AFIT/GTM/LAL/97S-3

APPLYING CROSS-DOCKING AND ACTIVITY-BASED COSTING TO MILITARY DISTRIBUTION CENTERS: A PROPOSED FRAMEWORK

THESIS

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Presented to the Faculty of the Graduate School of Logistics
and Acquisition Management of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Logistics Management

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September 1997

Approved for public release; distribution unlimited

Acknowledgments

The authors are grateful to many people for their generous gifts of time and knowledge that made this thesis possible. We start by thanking the man who challenged us with the research, Lt Col Terrance Pohlen. Despite many late nights when we felt we were in over our heads, we realize the goals he set before us "stretched" us, as professionals and as people, beyond our old limits. We thank Professor Bernard LaLonde for honoring us with his time and inspiration. Thanks are certainly due to Dr. Daniel Guide, Maj Mark Kraus, and Maj Alan Johnson of the AFIT faculty for their patient simulation modeling guidance. We also thank Lt Col Robert McCauley and Lt Col Kyle Johnson for hosting our first trip to the Pentagon and taking time out of their hectic schedules to advise us of contemporary vital concerns of the DoD we should address.

We were referred by Lt Col Johnson to "The Famous" Jerri Taylor, Domestic Traffic Manager of the DLA's largest distribution center. She turned out to be the golden source of information sought by every thesis researcher. Besides providing countless hours of interviews, Ms Taylor personally hosted us on tours through the distribution center. She provided us the resources of her entire staff and made us feel in every respect as important as the Heads of State she routinely hosts.

We thank Navy Captain Kenneth Wenzel and the DDSP staff members who took time out of their "more-with-less" schedules to teach us about military costing and distribution methods. We also thank Michael Hitchcock, our late-found, but appreciated sponsor, for his interest and advice. Finally, we owe a debt of gratitude to our advisor, Dr. William A. Cunningham, for his continual encouragement and faith.

Jonathan "Jon" P. Elliott   Dwight "Dan" H. Hintz Jr.

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Abstract

Current events and fiscal constraints have focused DoD planners' attention on reducing logistics costs and improving efficiency while maintaining effective combat operations support. Military leaders are seeking private industry best practices to help achieve these goals. Two commercially successful business practices that may help the DoD achieve its goals are cross-docking and Activity-Based Costing. Cross-docking is a commercially proven approach to material distribution through a distribution center that can help reduce inventories, speed material flows, and cut related logistics activity costs. However, the DoD is faced with the challenge of costing current and potential logistics processes with an antiquated costing structure. Military planners may be able to use Activity-Based Costing to answer this costing challenge and help them decide whether or not to invest in cross-docking technologies. This thesis is a proposed framework for constructing a tool that may provide managers performance and cost measurements of current military distribution center operations, and estimate expected performance and cost changes as a result of incorporating high technology cross-docking methodologies. The tool incorporates computer simulation modeling to measure the time performance, and a proposed Activity-Based Costing model to measure available versus used capacities, and costs, of existing and potential distribution processes and activities. The use of simulation for costing of activities and product cost allocation is an unexplored area of Activity-Based Costing in the literature. Furthermore, ABC and simulation have not been used in combination to simulate and cost specific activities in a DoD distribution center. The implication for this research is to provide DoD logistics planners a decision support tool for possible military distribution center efficiency, effectiveness, reengineering, etc., decisions.

APPLYING CROSS-DOCKING AND ACTIVITY-BASED COSTING TO MILITARY DISTRIBUTION CENTERS: A PROPOSED FRAMEWORK

I. Introduction

Background

The Chairman, Joint Chiefs of Staff, in his *Joint Vision 2010*, calls for "Focused Logistics" as one of four new operational concepts that, taken together, will provide America's Armed Forces "full spectrum dominance" (JCS, 1996:1). To support the Chairman's vision, Department of Defense (DoD) logistics planners have created their own vision for a logistics system that will provide reliable, flexible, cost-effective and prompt logistics support, information, and services to the warfighters, and will achieve a lean infrastructure. Their strategic plan states "The DoD Logistics System will meet this vision proactively by making selective investments in technology; training; process reengineering; and employing the most successful commercial and government sources and practices (DoD, 1996/1997:15-29).

DoD Logistics: Needed Improvements

Logistics improvements could provide significant savings for the DoD, without sacrificing military effectiveness. Logistics consumes approximately fifty percent of the total DoD budget (DoD, 1996/1997:1-2). Cold War DoD logistics stockpiled as many

spare assets as possible to ensure fast, reliable logistics support in the event of an actual war (GAO, 1997c:). According to Paul G. Kaminski, Under Secretary of Defense (Acquisition and Technology), "Our 'just-in-case' system has evolved over the years in response to a cumbersome acquisition system, little or no in-transit visibility, and a lack of a fast and responsive distribution [system]. This system is in stark contrast to the 'just-in-time' systems being implemented by commercial enterprises and our own industrial partners" (DoD, 1996/1997:2). Now, in the post Cold War, the DoD cannot afford to waste valuable dollars handling, storing, and maintaining gross stockpiles of spare assets. The DoD must rethink and reengineer the way it conducts its logistics business.

DoD logistics managers have been tasked to change from the effective combat support capability strategy of stockpiling to new, more efficient strategies and managerial techniques without any loss in effectiveness. As outlined in Air Force Logistics Management Agency's Megatrends Report (AFLMA, 1996), DoD logistics managers should focus their attention upon their private sector counterparts for strategies to operate more efficiently, while retaining or increasing efficiency. It makes good sense to learn from commercial sector businesses who fight and win battles of efficiency and effectiveness against their competition everyday.

DoD Logistics Goals

The DoD's *Logistics Strategic Plan* outlines the following specific goals developed to alleviate shortcomings in the DoD's logistics supply chain: 1) reduce logistics cycle times; 2) develop a seamless logistics system; and 3) streamline logistics infrastructure (DoD, 1996/1997:15-29). The DoD has begun to take a hard look at commercial industry best practices in logistics in the past few years (GAO, 1997b), as illustrated by Under Secretary of Defense Kaminski's comments (DoD, 1996/1997:2), to achieve such goals. Private sector industries, such as retail, have drastically shortened pipelines and have implemented pull rather than push supply chain strategies. These efforts have helped private firms cut inventories and associated holding costs, allowing them to invest in opportunities more profitable or less expensive than inventory.

Cross-docking: A Possible Solution

The Defense Logistics Agency (DLA), a huge player in DoD logistics, has already taken some ideas from the private sector and put them to use, in response to the DoD's drive to improve efficiency. Some of those ideas include electronic data interchange (EDI) and automated systems within DLA's distribution centers (DCs), for more efficient control and handling of materiel distribution. The DLA, however, could quite possibly further reengineer its supply chain to accomplish the three new logistics goals mentioned above. "Competition has forced private sector firms to cut costs by moving to 'just-in-time' inventory concepts that help keep inventories low, turn stock frequently, and fill

orders quickly while maintaining good customer service" (GAO, 1994:1). Many private sector firms have done this through use of modern cross-docking distribution techniques in supply chain distribution centers (Cooke, 1994:51). It seems feasible cross-docking could be applied in military logistics DCs as part of a DoD wide logistics supply chain reengineering effort to meet the three primary logistics goals of the *Department of Defense Logistics Strategic Plan.*

Cross-docking has many definitions, but, in general, can defined as "the direct flow [of inventory items through a distribution center (DC)] from the receiving function to the shipping function and eliminating any additional steps in between" (Rader, 1995). The application of modern cross-docking in DLA could enhance efficiency by reducing inventories, through reduction of pipeline times, and by transitioning DLA from a push to a pull supply chain. A push methodology in a supply chain distribution is where inventory is shipped in advance of demand and stored in field locations waiting for customer demand. Conversely, a pull supply chain methodology is where inventory is only shipped to meet customer demands as they occur.

Cross-docking also has the potential for enhanced effectiveness. With better communication and information transfer provided by EDI, more accurate, rapid, and effective shipping is possible. Thus cross-docking may very well help the DoD achieve its logistics goals of reducing cycle times, developing a seamless logistics system, and streamlining logistics infrastructure.

DLA's distribution centers use some cross-docking strategies. However, they may not be operating as efficiently and effectively as they could using the most advanced

cross-docking distribution methods employed in the commercial sector. DoD logistics managers need a way to decide whether or not implementing cross-docking techniques in military distribution centers is economically feasible, and whether or not it would help the DoD meet its logistics goals better than the existing distribution practices.

Activity-Based Costing

In reaction to increasing competition, private sector organizations have been required to find new methods to reduce costs and increase performance in order to survive and succeed. Reduction of costs is essential to maintain competitiveness and cost information happens to be one of the primary weapons that organizations can use in the struggle for survival and success in today's business environment (Compton, 1996:20). The mating of accurate cost information with an effective cost management system that produces intense pressures to reduce costs is essential (Cooper, 1996:26). However, traditional cost accounting systems, still used in businesses today, have been found to be inadequate and unreliable (Harr, 1991:24). Traditional accounting systems have begun to lead managers awry, giving them distorted views of true costs and leading to poorly informed decisions. Activity-Based Costing (ABC) was designed in attempts to alleviate these errors ("Cost Reduction…," 1995:10). Thus, private sector businesses have begun moving toward greater use of ABC because ABC offers managers, not only more accurate cost information for better strategic decision making, but also more relevant cost

information for better management of business activities, and resources (Beaujon and Singhal, 1990:51; Cooper and Kaplan, 1992:2).

Activity-Based Costing (ABC) can simply be defined as “a technique to more accurately assign the direct and indirect costs to the activities and products or services which consume an organization’s resources” (Pohlen, and others, 1995:36). As a result, ABC information increases managers’ abilities to effectively and efficiently manage their activities (Beaujon and Singhal, 1990:51). ABC does this by focusing managers’ attention on improving the activities which have largest impact on costs and profits, enabling managers to reduce costs and increase profits for a better competitive stance (Cooper and Kaplan, 1991:130).

ABC has quickly become one of the private sector’s best practices primarily being used in manufacturing organizations (Kennedy, 1996:24). However, ABC has been increasingly viewed as an appropriate technique to be applied to service organizations (Druker, 1995:55), including logistics organizations (Pohlen and others, 1995: 38) and government organizations, such as the armed forces (Lambert and Whitworth, 1996:24).

Government accounting systems are similar to traditional cost accounting systems found in the private sector (Harr, 1991:23), providing managers only with visibility of expenses by specific categories of expense and not providing managers with cost information needed to manage business activities and processes (Callahan, Marion, and Pohlen, 1994:37). In recognition of government accounting’s inability to provide managers with relevant cost information, Comptroller General Bowsher, in testimony to the House of Representatives, called for a sense of urgency in correcting the internal

control and cost accounting problems that have continually plagued governmental organizations (Geiger, 1995:48-49). In a 1993 report to Congress, Bowsher continued,

> Over the past decade, many private sector organizations recognized that they would have to change their cultures and processes to survive...The federal government is obviously not going out of business, but its ability and capacity to serve the public have clearly diminished. We must change the way we manage the government if we are to improve its efficiency and effectiveness and restore public confidence. (Geiger, 1995:49)

In recent years the government has enacted several mandates that have called for improvements in government managerial cost accounting. These are: 1) the Chief Financial Officers Act; 2) the Government Performance and Results Act; 3) the Government Management Reform Act; 4) the National Performance Review; and 5) the creation of the Federal Accounting Standards Advisory Board (Geiger, 1995: 49).

As one of private sector's best practices, ABC was studied to determine the applicability of Activity-Based Costing within a government service organization. The findings of Callahan and Marion's award winning research are summarized as shown on the following page (Callahan and Marion, 1994: 106-123):

1. An ABC system can be used to determine costs of activities within a government service organization.

2. A government service organization that implements an ABC system will realize differences in cost visibility of activity and process costs under each overhead department.

3. DoD managers are able to use information provided by an ABC system to determine activity and process costs, as well as resource allocation.

4. Government accounting systems do not link budget expenditures to costs of activities of processes.

5. Corporate ABC implementation procedures were able to implement an ABC cost model within a DoD service organization.

Follow-on research by Callahan, Marion, and Pohlen provides a methodology for implementing ABC in a government service organization (Callahan, Marion, and Pohlen, 1994:40). The methods established by their research may possibly be used to develop an activity based costing model of military DC processes and activities.

Currently DoD's financial management systems are inadequate for assessing the cost of current distribution center processes or the cost implications of reengineering efforts to improve distribution center activities and processes, such as for the implementation of advanced cross-docking methodologies. The application of ABC to a military distribution center could aid DoD logistics managers in costing current DC processes and activities, pinpointing specific activities and processes that could be made more efficient and effective by choosing and implementing economically feasible cross-docking techniques. Such information could support managers in making distribution

design decisions to affect cost reductions, improve cycle times, free up unneeded resources, etc., as will be demonstrated in Chapters Four and Five of the present research.

Computer Simulation Model

The proposed ABC costing model of a military DC could be used in conjunction with a computer simulation model of the same DC. Computer simulation is a unique tool that is well suited for assisting in the reengineering of business processes (Banks and others, 1996:8).

The advantages of computer simulation make it an excellent tool for the evaluation of complex military DC operations, consisting of many processes and activities. Simulation models can analyze the impact of process changes, identify bottlenecks in a system of processes, and can estimate cost implications of reengineering alternatives (Gordon and Gordon, 1996:377). A tremendous advantage of such simulation modeling is the capability to evaluate the impacts of DC design decisions without actually altering existing operations. This allows managers to avoid the costs of making bad decisions or see the possible savings of distribution methodology innovations such as cross-docking.

Decision Support Tool

A site visit by the authors, of one of DoD's largest distribution centers, in conjunction with extensive interviews of distribution managers and cost experts, revealed data necessary to drive a computer simulation model of a military DC is not tracked.

Lacking such data, a simulation model of a hypothetical generic DC, including typical activities and processes, may still be constructed to establish the basic framework for modeling actual facilities. Thus a computer simulation model of a generic military DC, in conjunction with an ABC model of the same operation, could be created to provide a framework for constructing a managerial decision support tool. Then DoD simulation and costing experts could use the proposed framework as a guide to create a decision support tool for their actual DC. Such a decision support tool could provide logistics managers both cost and time performance measures of existing DC processes and activities. Then the experts could alter the computer simulation and ABC models with changes to processes in the DC, such as the implementation of modern cross-docking techniques, and see the changes in both time and cost performance. This decision support tool could be used by logistics managers to help determine whether or not to modify military DCs for more efficient and effective DC operations.

Importance of Research

The importance of this research is to contribute to the modernization of the U.S. military logistics infrastructure, enabling the DoD to meet current and future mission requirements. The research should also contribute to increasing the efficiency and effectiveness of U.S. military logistics systems and provide an avenue for making informed investment decisions and reducing logistics infrastructure costs, specifically within DoD supply chain distribution centers. This research also furthers the research of

Callahan and Marion by combining an ABC model with a simulation model for use as a practical decision support tool for DoD logistics. The use of simulation for costing of activities and product cost allocation is an unexplored area in ABC literature (Raghu, Chaudhury, and Rao, 1997:3).

Problem Statement

DoD logistics managers know the DoD supply chain must be reengineered to reduce costs and improve performance to meet DoD's logistics goals. However, DoD logistics managers do not have a way to accurately measure costs or time performance of current or potential distribution centers to help them make reengineering decisions for improvement. They lack the appropriate performance measures, data accumulation procedures, and financial information necessary to build such a management decision tool.

Research Objective

The objective of this research is to provide DoD logistics managers with a framework for building a military distribution center costing and performance measurement simulation model that can be used as a management decision support tool. Such a tool, then, could be used to aide DoD logisticians achieve logistics goals, in support of *Joint Vision 2010*, by increasing the efficiency and effectiveness of the DC portion of the DoD logistics supply chain.

Research Questions

To meet the research objective the following research questions must be answered.

1. What information is necessary to build a computer simulation model as a management decision support tool?

2. What types of information is needed for an ABC model to cost DC activities?

3. Can an ABC model of military logistics activities and processes be meshed with a computer simulation model to provide DoD DC managers cost and time performance information to support DC design, quality, process improvement, cost reduction, reengineering, etc?

4. What information will the decision tool provide managers?

Scope and Limitations of the Research

This thesis will provide a framework for building a decision support tool for military DC managers. Originally, the research intent was to perform a simulation of an actual specific military DC, to provide cost and time performance data of DC processes as they exist, and then compare it with cost and time performance data generated by altering the simulation model to incorporate leading edge commercial cross-docking practices. However, site visits and interviews revealed the majority of data needed to drive such an assessment model is not recorded or tracked by the DoD. This includes data required to perform ABC analysis and data needed to construct a computer simulation model of a real-world DC operation. Therefore, the focus of this research was shifted from modeling a real-world DC operation to providing managers a framework for

building such a decision support tool. For this research, then, the data is not real-world, and is generated simply to demonstrate the kinds of data needed to construct the decision support tool and to demonstrate how the tool would be used to support evaluation of existing DC operations versus proposed operations, incorporating modern cross-docking methodologies.

The validity of the research, then, is limited by the appropriateness of the sample data generated to represent DC operations, and the appropriateness of the methodology for building the decision support tool. The emphasis, however, is not on the accuracy of the information generated by the analyses of current and proposed operations, but on showing managers the types of data needed, how to build the decision support tool, and the types of information such a tool may provide military logistics managers for support in making decisions for improving cost and time performance in a military DC.

Methodology

The methodology for accomplishing this research project will be to:

1) Conduct surveys of the literature on current best practices in DC strategies by commercial and DoD organizations and the use of ABC in commercial organizations, specifically logistics organizations.

2) Collect information about modern commercial cross-docking and military distribution centers.

3) Develop a generic computer simulation model of activities and processes within a military distribution center.

4) Develop an ABC model of those same activities and processes.

5) Perform a simulation experiment to evaluate the costs and time performance of the modeled activities and processes.

6) Alter the activities and processes of the model to incorporate high technology cross-docking strategies.

7) Perform a simulation experiment to evaluate the costs and time performance of the altered activities and process.

8) Draw inferences from the results about how costs and time performance should change as a result of implementing commercial best practices in cross-docking within a military distribution center.

Organization of Research

This chapter suggests the development of a computer simulation model as a DoD DC management decision support tool, applying ABC to accurately cost DC processes and activities. It proposes such a tool may be used to simulate DC operations versus cross-dock operations and how related costs should change. It is proposed this information could help logistics managers make informed decisions about reengineering DC operations to reduce logistics cycle times, develop a seamless logistics system, and streamline logistics infrastructure, in support of Joint Chiefs of Staff's Focused Logistics. Chapter Two conducts a literature review on the current and future environment and mission of the DoD, the role of logistics in DoD, and the concepts of cross-docking and ABC as aides for the effective and efficient accomplishment of the logistics mission. Chapter Three contains the methodology followed to accomplish the research for this thesis. Analysis and results of the research are in Chapter Four, and Chapter Five

summarizes the results of this research by offering concluding remarks, by pinpointing several limitations within this research, and by offering suggestions for future research..

II. Literature Review

Background

The end of the Cold War in 1990 signaled the beginning of a new era in American Defense policy (Dye, 1995:213,222). The U.S. Government has since made significant reductions in defense spending and infrastructure, in an attempt to parallel the reduced threat to national security and help alleviate federal deficit pressures (GAO, 1997d:5). The DoD concurrently reevaluated its mission and, despite continuing cut-backs, must find more efficient and economic ways to operate, with fewer resources, while increasing effectiveness, to meet new and changing global challenges identified in its latest mission statements (GAO, 1996a:2). In 1996 the Chairman, Joint Chiefs of Staff, set forth a plan to this end, called *Joint Vision 2010*, including an operational concept called "focused logistics" (Joint Vision 2010, 1996:1). In response, defense logistics planners have created their own vision to integrate focused logistics into the overall warfighting framework outlined in the *Department of Defense Strategic Logistics Plan* (DoD, 1996/1997:1).

The GAO has identified inventory management as one area where the DoD could improve logistics efficiency and effectiveness, while reducing costs, to help achieve such goals as focused logistics. The DoD currently has billions of dollars worth of inventory considered unneeded to be on hand to support war reserve or current operating requirements, costing hundreds of millions of dollars annually in inventory carrying costs

(GAO, 1997d:3). The Defense Logistics Agency (DLA) manages supply operations for all the services (DDRE, 1996:3), and although it has had some success in addressing its inventory management problems, DLA has not yet tested the most innovative commercial inventory management practices (GAO, 1997d:10).

In sharp contrast, competition has forced private sector firms to cut costs by moving to "just-in-time" inventory concepts that help keep inventoryies low, turn stock frequently, and fill orders quickly while maintaining good customer service (GAO, 1994:1). The DoD's *Logistics Strategic Plan* specifically calls on the DoD Logistics System to employ the most successful commercal and government practices to help reduce logistics response time, develop a seamless logistics system, and streamline logistics infrastructure (DoD, 1996/1997:4). Three leading edge practices may possibly be used together to help the DoD achieve these logistics goals by improved inventory management within a military distribution center.

The first practice, cross-docking, is "one of the hottest low-inventory practices in [commercial] warehousing today" (Harrington, 1995:26). The DLA may be able to cut time and costs out of the DoD supply chain by reengineering to incorporate modern cross-docking techniques into military distribution centers (DC). Such a reengineering decision, however, would require accurate cost information of current and reengineered DC operations. Activity-Based Costing (ABC), the second leading edge commercial practice, may possibly be applied to make such cost-benefit comparisons. The third leading edge practice, often employed by both government agencies and commercial companies, is computer simulation modeling. Simulation modeling is needed to evaluate

complex military DC operations, consisting of many processes and activities. Simulation models can be used to analyze the impact of process changes, identify bottlenecks in a system of processes, and can estimate cost implications of reengineering alternatives (Gordon and Gordon, 1996:377), such as for cross-docking.

Chapter Overview

This chapter has four main sections, each broken into individual segments for clarity of focus. The first section will be a review of the literature outlining the current challenges of the DoD environment, particularly in logistics and inventory management, and focuses down to the military distribution center as one possible area for pursuing the logistics goals DoD planners have set for success in this new environment. The last three sections focus on leading edge commercial and government practices that may possibly be combined to help the DoD achieve focused logistics. The second section will be a literature review on cross-docking. The third section will be a literature review on Activity-Based Costing, and its potential application within a military logistics environment. Finally, the fourth section will be a brief literature review on the use of computer simulation modeling, wherein the concepts of cross-docking and ABC may be applied to create a decision support tool for logistics managers contemplating improvements to military DC operations, with the overarching plan of meeting the contemporary logistics goals set by DoD planners.

Section One

DoD Environment

The Cold War ended with the dismantling of the Soviet Union in 1989. Communism and the great threat it represented to American Goals and Interests all but seemed to vanish along with the Soviet Union. In the absence of this threat, mounting Federal Budget Deficit problems and intense public scrutiny to reduce it brought extreme pressures to cut costly defense budgets and redundant military infrastructures. The Deficit has exceeded $127 billion every year since 1982 (IBERT, 1996:1).

These environmental factors have forced the Department of Defense (DoD) to operate on increasingly reduced budgets, forcing reductions in military force sizes and removal of forces from overseas locations (JCS, 1996:8). Since the end of the Cold War, the United States has significantly decreased its defense force structure and spending. For example, from 1989 to 1995 the number of DoD active duty army, navy, air force, and marine personnel decreased from 2.1 million to 1.5 million; The number of attack and fighter aircraft were cut from 2,800 to 1,784; The number of ships was reduced from 570 to 372; The value of inventories held to support DoD forces dwindled from $92.5 billion to $69.6 billion; The defense budget dropped from $291 billion to $252 billion (GAO, 1997d:5).

Despite these cutbacks, threats to American interests still remain and do so with even greater uncertainty than in the past. Today, access to advanced technologies,

modern weapons, and weapons of mass destruction is more available than ever. This sobering fact, coupled with the realization that states which oppose American interests still exist throughout the world, indicate potential adversaries have the ability to threaten U.S. national security (JCS, 1996:10).

U.S. Defense Policy

The current U.S. defense plan recognizes the potential of multiple threats. It's goal is to maintain sufficient forces to fight and win two nearly simultaneous major regional conflicts (Dye, 1995:216). And while there is much debate whether or not this can be accomplished with current force levels or those projected by the 1993 DoD Bottom-Up Review (Ciccotello and Green, 1995:59-60; Dye, 1995: 216; Spring, 1993: 1-3), the military will not lose the responsibility to carry out its mission: "The American people will continue to expect us to win in any engagement, but they will also expect us to be more efficient in protecting lives and resources while accomplishing the mission successfully" (JCS, 1996:8).

In 1996, the Chairman, Joint Chiefs of Staff, presented the DoD with his *Joint Vision 2010* as a conceptual template to meet the challenges of DoD's current and future environment. The focus of this vision is on achieving dominance across the range of military operations, and rests on four operational concepts: dominant maneuver, precision engagement, full dimensional protection, and focused logistics (JCS, 1996:1).

Importance of Logistics

Gen John M. Shalikashvili, Chairman of the Joint Chiefs of Staff, stated: "Logistics is the foundation of combat power" (DoD, 1995: Cover Letter). *Doctrine for Logistics Support of Joint Operations* (DoD, 1995), formally defines logistics as "the process of planning and executing the movement and sustainment of operating forces in the execution of military strategy and operations." History shows logistics has been the major limiting factor in a nation's ability to wage military operations, indicating the relative combat power a nation's military can deliver depends directly upon logistics' ability to supply forces and materiel to the correct points across the range of military operations (DoD, 1995: I-1).

Focused Logistics

Focused Logistics is the key to optimizing the other three operational concepts set forth in *Joint Vision 2010* (JCS, 1996:24). The vision calls on logistics to provide Total Asset Visibility, contributing to operational commanders' "dominant battlefield awareness." This includes providing the commander a complete awareness and understanding of available support, the need for future support from all units, and a seamless logistics system. It also tasks logistics to help provide "dominant battle cycle time," including the ability to turn inside an adversary, act before the adversary can act, and even act before the adversary's dominant battlefield awareness system can see you act (DoD, 96/97:1).

Despite its importance to the operational mission, DoD planners must weigh the tremendous costs of logistics against the importance of modern operational equipment for the battlefield, whenever a major reengineering plan is tabled to support Focused Logistics. Logistics consumes approximately fifty percent of the total DoD budget. Thus every dollar spent on logistics for outdated systems, excess capability, and unneeded inventory is a dollar unable to extend U.S. warfighting capability (DoD, 96/97:1).

The Inventory Challenge

Currently, and for decades, the DoD has had chronic problems with inventory management, resulting in billions of dollars in unnecessary spending, within its logistics supply chain (GAO, 1997b:1). During the Cold War, it was essential to transport and store "just-in-case" inventories. Money was available and these "just-in-case" inventories were "pushed" through the supply chain and stored for the critical time when they might be needed. As a result, the inventory system was slow, lacked responsiveness, and lacked in-transit asset visibility (DoD, 96/97: 1-2)—all contrary to the concept of the new Focused Logistics. No less than 30 GAO reports have been written since 1991 specifically documenting this problem (GAO, 1997b:1).

In contrast, private industry has designed systems that act much differently than the logistics systems of the military. The private sector, in efforts to meet customer demands while reducing expensive inventories, employed "just-in-time" systems that "pulled" inventories to sources of demand. The DoD needs to move closer to the "pull"

systems developed in the private sector (DoD, 96/97: 1-2) (GAO, 1997d:9). This represents a tremendous opportunity within logistics for the DoD to achieve savings and increase efficiency, while maintaining or improving effectiveness.

In 1990 the GAO initiated a special effort to review and report areas in government considered to be of high risk in fraud, waste, abuse, and mismanagement (GAO, 1997b:3). Since then, the GAO has conducted intense "high risk" reviews of DoD inventory management. In reports of each of these reviews, the GAO identified extensive problems in DoD inventory management practices. In general, the GAO reported large amounts of unneeded inventory, inadequate inventory oversight, and slowness to implement modern commercial practices (GAO, 1997d:9).

DoD Unneeded Inventory

Maintaining inventory that is not needed is expensive and does not contribute to an effective, efficient, and responsive supply system (GAO, 1997c:7). Estimates by inventory and logistics experts show inventory carrying costs could range between 12 and 35 percent as a percent of inventory value (Lambert and Stock, 1993:366). In September of 1995 DoD secondary inventory was valued at $69.6 billion, about half of which included items not needed on hand to support DoD war reserve or current operating requirements (GAO, 1997d:3).

Overall, the GAO estimates the DoD could save about $382 million annually in inventory holding costs just by eliminating inventory at non-major locations that is not needed to meet current operating and war reserve requirements (GAO, 1997c:9).

Inadequate Inventory Oversight

Most DoD general issue spare and repair parts are stored at few major locations managed and operated by the Defense Logistics Agency (DLA), with the remaining stored at hundreds of other service-managed locations. For example, 96 percent of air force inventory is stored at six major DLA locations and the other 4 percent is kept at 105 non-major locations. Over 53 percent of the total DoD inventory item types stored at non-major locations are in quantities of three or less and had no issues over a two-year period from 1994 to 1996, while only 25 percent are stored in quantities of 11 or more (GAO, 1997c:3). According to the GAO, this results in approximately 2.2 million different types of inventory items that do not need to be on stock. Worse still, DoD has more than a 20 year supply for some items, and many other items have deteriorated or become obsolete (GAO, 1995:1).

At the DLA storage locations, DLA performs the receipt, storage, and issue functions and bills the services for these functions. Storage costs range from $.48 per square foot for open storage to $5.15 a square foot for covered storage. The charge is not based on the space the particular item occupies but rather the square footage assigned to it (GAO, 1997c:7). So, if a pack of washers is being stored in a bin, the storage cost is

based on the bin size and not the number of washer packs in the bin. Therefore, if washers are being stored at numerous locations, a storage cost is charged at each location, when all the washers could be consolidated into one location.

The reports did not mention how much square footage is used by the services, but one report estimated that DoD secondary inventory occupies about 218.8 million cubic feet, and that 60 percent of this is not needed to satisfy current war reserve or operating requirements. The GAO did concede, however, that "many" of the items may have potential future use (GAO, 1995:1). In monetary terms, the GAO estimates that inventory at the non-major locations is valued at over $8.3 billion, of which $2.7 billion is not needed to meet current operating or war reserve requirements (GAO, 1997c:1).

Specific Examples

The GAO's reports include extensive accounts of specific examples where the DoD is poorly managing inventory. For purposes of brevity only three are given in this paper. However, to illustrate the range of problems, the examples shown here are each of a different magnitude of cost impact to the government.

At a time when commercial companies are cutting costs by minimizing stocks, the DoD continues to store redundant levels of clothing and textile inventories. For about 26 percent of such items, the DoD had a 10 year supply on hand as of 1994, incurring unnecessary inventory storage and handling costs. (GAO, 1994:1)

The DoD also has many instances of overstock identifiable down to the sku. For example, one type of truck engine, with a unit price of $7,010, has a current operating and war reserve total requirement 214 engines. Within the DoD, there are 360 of these engines at four major storage locations (combined) and 543 more at two non-major locations. Each engine and its container occupy 53.6 cubic feet and the total storage space occupied by the 543 engines at the two non-major locations is 29,104 cubic feet. This means that, if the GAO figures of operating and war reserve requirements are correct, all engines at the non-major locations could be disposed of, the storage space could be freed , and their related storage costs could be eliminated. That does not include reducing the number stored at major locations down to where operating plus war reserve requirements are just met. (GAO, 1997c:6)

A similar situation exists with thousands of skus. One more example given effectively illustrates excessive spending and potential for tremendous savings. Consider the case where a small ring spacer is kept in quantities of one or two, in large bins, at non-major locations, where required operational and war reserve inventory levels of the same sku are met or exceeded with quantities kept at the major locations. According to GAO figures, there are thousands of such cases (GAO, 1997c:8). Recall from above that the DLA charges the services $5.15 annually per square foot occupied by the bin holding the one or two items, and the bins each have the capacity to hold hundreds of their respective sku. Now consider that the value of each item is in the one dollar range. Thus, the DoD is spending far more each year to store each of thousands of skus than the skus are worth (basically, paying for the same items over and over again).

Improvements in Inventory Management

In 1990 the Pentagon took a giant leap forward toward improving its inventory management. In the past, the services each owned and managed their own logistics support distribution networks. This caused redundancies in transportation, storage, and similar logistics functions. The Deputy Secretary of Defense directed a review of these practices in 1989, and by 1990 the review committee came up with the DLA as a way to manage the services' consumable items with less resources than required by the services, saving money, and improving overall efficiency within the DoD. DLA, in keeping with the envisioned joint mindset, is the primary logistics support agency for all the defense service branches (DDRE, 1996:3). Accordingly, Defense Management Report Decision 926 directed that the DLA assume management for 1 million consumable items (89 percent of DoD consumables) from the services between August 1991 and the end of FY97 (CIT:2). The relatively new agency has already adapted leading edge practices, such as using optical laser cards for automated manifests (DLA's Optical Laser Card, 1993:4-5; Innovative Digitized Manifests, 1996:61). DLA has also begun to incorporate Total Asset Visibility (TAV) and radio frequency (RF) technology in defense logistics to support the joint vision of U.S. national security in the 21st century (Peters, 1996:46; Saccomano, 1995:43-44).

Since its inception, the DLA has also worked to implement commercial best practices to improve its inventory distribution and management. DoD concurred with the draft of a January 1997 GAO report on its inventory practices. Accordingly, DLA is coordinating with the military services to reengineer the DoD distribution system with the

objective of providing greater responsiveness to the customer and increasing efficiencies in receiving, storing, and shipping spare parts inventories (GAO, 1997c:10).

Since 1993, DLA has begun using prime vendor programs for personnel items, such as medical supplies and pharmaceutical products. The GAO estimates that between 1991 and 1996 DoD reduced pharmaceutical, medical, and surgical inventories and associated management costs by approximately $714 million through the use of best practices, such as the recent prime vendor programs. At one storage depot alone, DLA reduce storage space used for medical and pharmaceutical items by about 40 percent over three years (GAO, 1997b:9).

Overall, the DoD has made some perceptible reductions in its inventory glut. During the 1992 through 1995 fiscal years, DoD disposed of secondary inventory items valued at $43 billion (GAO, 1995:1). The DLA has also started direct vendor delivery for food, as well as medical, items. But the inventory reductions have largely been due to reduced force levels which reduced overall demands on DOD's defense logistics systems, and the direct vendor deliveries address only about 3 percent of the items for which this concept could be used (GAO, 1997d:1). And despite DoD attempts at improving its inventory management practices, progress has been slow. Admittedly, many efforts have been partially offset by decreasing inventory demands and increasing returns of materials by deactivated forces in the recent defense draw downs, as mentioned earlier. Much of the sluggishness, however, is due to DoD's long standing culture belief that it is better to overbuy items than to manage with just the amount of stock needed (GAO, 1997d:3).

Paul G. Kaminski, Under Secretary of Defense (Acquisition and Technology), summed up the DoD inventory scenario:

> Our 'just-in-case' system has evolved over the years in response to a cumbersome acquisition system, little or no in-transit asset visibility, and lack of a fast and responsive distribution. This system is in stark contrast to the 'just-in-time' system being implemented by commercial enterprises and our own industrial partners. Neither the 'just-in-case' or the 'just-in-time' system are right for the DoD. A tailored approach is needed. Right now, the pendulum is too close to 'just-in-case.' In needs to swing more to a leaner 'just-in-time' position. (DoD, 96/97:2)

The Way Ahead

The *DoD Logistics Strategic Plan* is the document that outlines the shortcomings of DoD logistics and has set specific strategic goals to reengineer DoD's inefficient system into an effective reality that is proposed and demanded by *Joint Vision 2010.* The *DoD Strategic Logistics Plan* gives the following goals to support this vision (DoD, 96/97: 4):

- Provide reliable, flexible, cost-effective and prompt logistics support, information, and services to the warfighters.
- Achieve a lean infrastructure.
- ...The DoD Logistics System will meet this vision proactively by making selective...investments in technology, training, process reengineering, and employing the most successful commercial and government sources and practices.

As outlined in the plan, specific goals have been developed to alleviate shortcomings in the DoD's logistics supply chain. These goals are as follows (DoD,

96/97: 15-29): 1) Reduce Logistics Cycle Times; 2) Develop a Seamless Logistics System; and 3) Streamline Logistics Infrastructure.

Logistics Cycle Time (Goal 1)

The current DoD logistics supply chain is characteristically slow and non-responsive. This poor performance requires expensive, excess inventories while also undermining customers' confidence in the supply system. A major change in the supply chain is needed to guarantee rapid response to DoD's customer demands. This rapid response will ensure capability which is necessary for supporting a highly mobile force, responding to multiple contingencies, responding to the most current customer requirements, minimizing investments in inventories, and reducing investment in unneeded facilities and supply chain infrastructure (DoD, 96/97:15). Furthermore, total asset visibility is required to effectively maintain efficient and proper response to customer demands. Total asset visibility (TAV) is defined as "the ability to gather information from DoD systems on the quantity, condition, location, movement, status, and identity of material, units, personnel, equipment, and supplies anywhere in the logistics system at any time, and to apply that information to improve logistics processes, such as filling customer orders and improving the handling of shipments or the repair pipeline" (DoD, 96/97:18). TAV provides logistics managers an essential tool to efficiently allocate and properly deliver inventories to the right place at the right time (DoD, 96/97:18). Private industry has already made vast efforts to achieve such goals as

faster response to customers and better managing of inventory through asset visibility (DoD, 96/97:15).

Develop a Seamless Logistics System (Goal 2)

The importance of this goal is to realize that the logistics supply chain must be reengineered. The DoD supply chain must provide a constant flow of logistical information and must maximize the effective coordination and execution of all supply chain functions. To do so, logistical systems must be modernized and must be tied together through improved communication of logistical information (DoD, 96/97:22).

Streamline Logistical Infrastructure (Goal 3)

The importance of this goal is to realize that logistical infrastructure must be reduced. Reduction of excess infrastructure is essential for the DoD to meet shrinking budgets while still maintaining a capable operating fighting force. Cold War infrastructures can no longer exist and better, cheaper ways to provide logistical support to our forces must be found. Implementation of successful business practices must be accomplished. This will lead to reductions in inventories and reduced lead times. It may even be necessary to increase DoD logistical outsourcing to draw upon private sector abilities (DoD, 96/97:25-26).

Reengineering

Thus, there is a call to reengineer DoD's logistical supply chain. A customer approach must be developed in order to quickly respond to customer demands. DoD supply chain cycle times must be reduced. Total asset visibility must be realized to effectively and efficiently manage inventories. The supply chain must be better coordinated through greater use of modern information systems. Finally, the supply chain infrastructure must be reduced. This will save money, allowing shrinking DoD budgets to maintain capable operational forces. To do so best private sector practices must be implemented. The DoD's logistical supply chain is not efficient and it is not adequately effective toward meeting customer requirements. The supply chain must be reengineered if America's Armed Forces are to be successful in the future armed conflict.

The Clinger-Cohen Act of 1996 recognizes the need for federal agencies to reassess their processes for potential reengineering. This act builds upon two previous Acts mandating management reform. First, The Government Performance Results Act of 1993 requires agencies reassess and redefine their organizational goals, missions, customers, performance measures, and improve organizational performance through sound strategic planning. This act determines where reengineering is supposed to start (GAO, 1997a:8). Second, the Chief Financial Officers Act of 1990 outlines the need for government agencies to improve their financial management and reporting practices. Appropriate financial systems are necessary to provide accurate data crucial for measurement of performance and reduction of agencies' operational costs. This act

determined accurate financial measures are necessary for process reengineering (GAO, 1997a: 9).

With the groundwork laid in these two acts, the Clinger-Cohen Act of 1996 was passed to ensure federal agencies appropriately apply new technology when reengineering processes. Work processes, information, and technology are all dependent upon one another. Simply applying new technologies to old processes will not achieve desired improvements in performance. This is so organizations do not buy new technologies and apply them to old non-optimal processes. Redesigning should determine the technology needed, not the other way around (GAO, 1997a: 9).

The DoD supply chain is outdated, costly and offers poor service. It needs reengineering to meet the goals outlined in the *DoD Logistics Strategic Plan.* But where do DoD logistics managers start? Private sector organizations have already successfully reengineered their supply chains for savings in time and cost, while increasing customer service. The DoD can benefit from studying private sector firms who daily fight efficiency and effectiveness battles for survival. The *DoD Logistics Strategic Plan* states:

> The DoD Logistics System will meet [the strategic logistics] vision proactively by making selective investments in technology; training; process reengineering; and employing the most successful commercial and government sources and practices. (DoD, 1996/1997:4)

The next three major sections of this chapter are literature reviews of three commercial sector best practices that, taken together, may be applied within the military distribution center to help achieve the DoD's Focused Logistics goals.

Section Two

Introduction to Cross-docking

DoD is striving for more efficient management of its existing inventory systems and looking to make greater use of proven commercial practices for cost savings. One focal point of the inventory challenge within the military logistics supply chain is at the distribution center (DC). In the supply chain, items (parts, supplies, materiel, etc.) are sent by a shipper, via some form of transportation, to a military DC. There the items go through some combination of or all of the following steps: receipt, breakbulk, inspection, labeling, storage, retrieval, packaging, sortation, consolidation, and shipping. From the DC, the consolidated items are shipped via some form of transportation to the waiting customer. The DLA, within the DoD, uses such DCs to move the vast majority of its supplies from vendors, shippers, or its own storage locations to the operating sites and units in all of the service branches.

DCs are not unique to the military. The DoD can look to the most successful commercial distribution operations for ways to improve operations. As outlined in Air Force Logistics Management Agency's Megatrends Report (Walker, 1996), DoD logistics managers should focus their attention upon their private sector counterparts for strategies to operate more efficiently, while retaining or increasing effectiveness (GAO, 1997b:1; DoD, 1996/1997:4; JCS, 1996:24)). It makes sense to learn from commercial

sector businesses who fight and win battles of efficiency and effectiveness against their competition everyday.

A major competition strategy among American firms in the last few years, particularly retail, grocery and distribution companies, is to focus on logistics for cost and time savings (Garry, 1995:28). Large firms with enough assets are building their own high technology distribution centers to achieve the most efficiency and cost savings within the limits of current know-how (Auguston, 1995:36-39; Bowman, 1994:52-56; Forger, 1995:36-39). Many companies with less purchasing power are finding unique ways to improve logistics with existing facilities, or forming partnerships in the supply chain, to squeeze savings out of their logistics operations (Garry, 1995:14; Harps, 1996:32-33; Weinstein, 1994:38).

One of the leading commercial logistics practices common to these initiatives is "cross-docking" (Troyer, 1995). Modern forms of cross-docking have provided commercial companies the improvements in time and cost performance DoD is looking for within its own DCs (Inventory Management: New Rules, New Game Plan, 1991:12B; Harrington, 1993:66; Kenedy, 1995:58). Therefore, it makes great sense for the DoD to learn from these commercial successes, analyze whether or not some form of cross-docking may help achieve its logistics goals, and implement cross-docking where it is cost effective and appropriate to do so.

Cross-docking is "one of the hottest low-inventory practices in warehousing today" (Harrington, 1995:26). Yet, the authors could not find the word "cross-docking" (as it applies to supply chain distribution) in any Defense Technical Institute Center

academic or research reference listings. Conversely, the authors found articles about cross-docking in virtually every one of the commercial logistics-related publications published in the past few years. Therefore, it is immediately apparent the DoD may learn ways to improve its logistics performance substantially by researching modern cross-docking methods for possible implementation in military DCs.

Overview

This second section of chapter two presents a literature review on cross-docking, a commercially successful supply chain distribution technique. The review will cover definitions and descriptions of the types of cross-docking. Next the section will discuss some of the environmental forces causing the move to cross-docking. Next it will discuss the information technology requirements for successful cross-docking. The section will conclude with reviews on the challenges and benefits of cross-docking.

Cross-docking Definition

Cross-docking can simply be defined as the processing and movement of materials from receiving to shipping in minimum time while eliminating unnecessary handling and storage steps (Schwind, 1996:59; Andel, 1994:93; Tompkins, 1995:). This is not a new concept. In the 1950s, companies brought box cars into freight houses located in a city. The freight house had rail siding on one side, a truck dock on another. When a box car arrived, the seller notified its customer, who came downtown to pick up

their goods. (*Cutting Costs with Crossdocking*, 1995:2). Basic forms of cross-docking have actually been around since the time of the caravan (Harps, 1996:33), but can be combined with today's technology to speed products to the customer while eliminating excess inventory.

Today, there are many types and levels of cross-docking. As with any other concept applied in the real world, there are likely as many descriptions of cross-docking as there are cross-docking operations.

Specific Definitions

The rather broad definition given above is refined into three specific definitions by Tompkins Associates Incorporated (*Cross-docking in the 90's*, 1995). These more specific definitions are described in the following paragraphs.

Manufacturing Cross-docking (current, future, and direct receiving)

Rather than placing finished goods coming off the assembly line into warehouses, finished goods are processed and moved to the outbound dock for consolidation and shipment. "Current manufacturing cross-docking" provides for finished goods to move directly off the line and into an awaiting truck van with no placing of the good onto the floor. "Future manufacturing cross-docking" allows finished goods to come off the line and are stored shortly in a staging area near the outbound dock. This staging allows time

for processing and consolidation of truckloads. Lastly, "direct receiving manufacturing cross-docking" is essentially the same as JIT (Tompkins, 1995:1).

Terminal Cross-docking

This is the most basic form of cross-docking—it focuses on consolidating customer orders. Different trucks arrive inbound to a breakbulk terminal or distribution center. Each truck has a few items destined for an identical customer. At the inbound docks, orders are unloaded from the trucks, sorted, and mixed, and full customer orders are reconsolidated for outbound shipment. What used to be several separate loads/orders to a single customer, is now consolidated into one load/order for one delivery to the customer. This cross-docking does not appear all that different from distribution methods of the recent past; however, in the past, there was more handling and storage involved than there is in cross-docking (Tompkins, 1994:94).

Distribution Center Cross-docking (current and future)

"Distribution Center cross-docking" is a mix between "manufacturing" and "terminal" cross-docking. Full loads arrive at the cross-docking distribution center (DC). All loads are identified after coming off the truck. Once identified, these loads are broken down into various products (not orders as in terminal cross-docking), usually in case sizes. These cases are routed through the DC (cross-docked) and shipped out after consolidation. "DC cross-docking" can be a current operation. Current cross-docking allows for all products to be cross-docked from the inbound truck directly to the

outbound truck without any storage or staging. On the other hand, "DC cross-docking" can be a future operation where products are staged temporarily for shipments later in the day (Tompkins, 1994:94).

Crossdocking Strategies

In addition, the three definitions of cross-docking can be conducted with one of three different strategies as identified by J. Eric Peters, consultant with Tompkins Associates Incorporated (*Cutting Costs with Crossdocking*, 1995:2). Essentially these three strategies can be viewed as three different levels of complexity in cross-docking. These are described, as before, in following paragraphs.

Unsorted/Unlabeled

This is a strategy of cross-docking where incoming products, cases, or cartons have not yet been sorted per order/customer or labeled for a particular order or customer. As a result, the inbound truckloads must be broken down, sorted, labeled and consolidated before being placed for shipment in the outbound truck. This strategy is simple in that it requires no preplanning or coordinated to presort and pre-label products, but it requires much more handling and storage than more complex strategies (*Cutting Costs with Crossdocking*, 1995:2).

Unsorted/Labeled

All inbound truckloads are unsorted per order/customer and must be broken down. However, all products, cases, or cartons have been pre-labeled so that conveyors can automatically sort and move products to the outbound staging area. There the products are consolidated for outbound shipment. This strategy seems to be the most common. It is not as complex as the next strategy, but requires a bit more handling and expensive automation of conveyor systems (*Cutting Costs with Crossdocking*, 1995:3).

Sorted/Labeled

All truckloads arrive at the inbound dock already sorted per customer/order. Once identified, the load can be directly moved to the outbound truck for shipment. This strategy is more complex, but allows for the least handling and storage (*Cutting Costs with Crossdocking*, 1995:3).

The Move to Cross-docking

In commercial industries, "people have gone berserk reducing inventories from storage," says Tom Speh, Professor of the Warehouse Education Research Center (WERC) at Miami University, Oxford, OH. However, Tom Sharpe of WERC says storage should not be the key focus, but movement of inventories, with better handling (Muroff, 1995:12).

Cross-docking can eliminate the intermediate handling and storage functions, and there associated costs (Andel, 1994). But if implementing cross-docking has such benefits, then why isn't every company using it? Cross-docking is a great idea for some, but not all companies. Mass merchants such as the "Big Three," Wal-mart, Kmart and Target, representing about one-third of the $229 billion in sales by the nation's top 200 discount retailers in 1991, have led the way with logistics technology (Bonney, 1994). These industry giants are creating tremendous pressures on suppliers to provide smaller, more frequent deliveries of product, faster.

Focus on Inventory

This key focus on inventory movement has been further explained by Bernard LaLonde, Raymond E. Mason Professor of Transportation and Logistics at The Ohio State University, when he talked about his Ohio State study and new trends in commercial logistics. He was quoted as saying, "Everyone is trying to get stuff out the door. They are all aggressively looking at flowing product directly to the customer. The conclusion that inventory will be stored seems impossible." His Ohio State study revealed that, by the year 2000, annual inventory turnover rates will be at higher levels than ever. Company plant warehouses are expected to have average inventory turns of 19.4 in 2000 as compared to average turns of 13.1 in 1994. Likewise company field warehouse turns are expected to rise from 9 in 1994 to 13.9 in 2000 and public warehouse turns should rise from 11.1 to 16.4 (Muroff, 1995:12).

The discussion about increasing inventory flows follows the main line of thought in commercial logistics today. Private industry is changing their logistics strategies from pushing inventories to customers at periodic intervals to "pulling" inventories through the supply chain to meet customer demands (Cooke, 1995:55). Industry flow-through networks of Efficient Consumer Response (ECR) in grocery, Just In Time (JIT) in manufacturing, and Quick Response (QR) in retail industries all follow the pull line of thought.

Pull Logistics Drivers

"Pull" logistics focuses on smoothing product flow to shorten cycle times, reduce supply chain inventories, and overall logistics costs while providing high customer service. (Harrington, 1993:64). The new philosophy of cross-docking is the common denominator that enables the flow-through networks of ECR, JIT and QR to function efficiently and effectively (Cooke, 1995:55).

Efficient Customer Response (ECR) is the trend in the grocery industry that employs cross-docking to squeeze costs out of the supply chain. Cross-docking eliminates costs (Garry, 1993:107; Casper, 1994:25). Ken Wagar of PMG Inc., Grand Rapids, MI stated that if done effectively and correctly, ECR, with cross-docking, can cut 50% or more off the cost of moving a case through a traditional grocery store flow path (Harps, 1996:33). The manufacturing industry with JIT uses cross-docking in much the same way the grocery industry does with ECR (Harps, 1996:33). Cross-docking is most

widely used in the retail industry where large amounts of goods are regularly demanded in easily predictable quantities from familiar, often-used vendors (Harrington, 1993:64). Fred Meyer's general retail merchandising group claims cross-docking is the key for their QR process. Mary Sammons, Fred Meyer's senior vice president, summed up why they use QR and cross-docking by saying, "There are two groups of businesses today, the quick and the dead (Halverson, 1995:6). Commercial companies today may have to cross-dock to survive.

What it Takes to Cross-dock

Firms considering cross-docking must consider whether or not it is appropriate, and what form of cross-docking to implement to achieve the best overall performance. For the DoD or any other organization to take full advantage of cross-docking, it may have to make use of many forms of cross-docking. This is because the DoD uses and consumes such a wide variety of inventory, with varying sizes and demand patterns. The swiftest forms of cross-docking rely heavily on modern technology. The following paragraphs describe the main information technology components required to employ the most efficient and effective cross-docking methods.

Information Systems in General

The key to getting the most out of cross-docking is information technology (Cooke, 1996:1; "Cutting Costs with Cross-Docking," 1995). The types of modern

information systems logistics managers can employ to enhance cross-docking efforts include automatic data collection (ADC), including bar-coding and radio-frequency (RF) technologies, effective electronic communication with electronic data interchange (EDI) and advanced shipping notices (ASNs), Transportation Software, Warehouse Management Systems (WMS), and people. Computer simulation is also a tool managers can use to improve cross-docking operations, however the review on computer simulation is discussed in section four of this chapter. The following paragraphs describe the specific information systems beneficial to modern cross-docking.

Automatic Data Collection for Cross-docking

ADC is critical. Pallets, cases, or cartons coming into a cross-docking facility should be pre-labeled. Pre-labeling would include bar-codes or radio-frequency transmitters placed upon arriving inventory that allow scanning devices to automatically record what is coming off the truck. Identification of the stocking keeping unit (sku) or product and its related information, such as weight, destination, quantity, etc., with ADC enables fast, automated sortation and rapid flow to correct outbound docks by personnel or by automatic conveyor systems. Once cross-docked, new shipping labels may need to be placed on inventories for shipment, depending upon the level of pre-coordination throughout the supply chain. Many suppliers and manufacturers are increasingly required to pre-label all item leaving their hands. These "label compliance programs" are starting to be commonplace because it is so critical to successful cross-docking (Wurz, 1994:96; Cooke, 1996:3; "Crossdocking in the 90s," 1995:9).

Bar-coding for Cross-docking

Only automatic data capture of bar code information can track products with the speed and accuracy required to provide flow-through replenishment (Automatic I.D. News, July 1995), the retail phrase for cross-docking. Unfortunately, only 10 percent of warehouses in the US have any automation at all now, but companies will have to change that for survival, according to Dan Trew, director of logistics at Catalyst, Inc., Milwaukee, Wis. (Lipp, 1996). With the help of automatic data collection, bar codes, and intelligent software control, managers can facilitate immediate cross docking; improve data timeliness by collecting data via bar codes as each operation is performed, thus reducing or eliminating paperwork and manual keying of data; ensure inventory and location accuracy; increase inventory turns with better customer service, since scanning bar codes means faster, more accurate order filling; optimize shipping, since bar codes can be used to verify order contents and automatically generate shipping manifests (Trunk, 1994).

Bar-coding is used throughout the supply chain to facilitate the supply function. Consumer demand information is acquired when the clerk at a point-of-sale terminal uses a bar code scanner to scan the UPC symbol on each product sold. Store computers maintain continuous records of product sales and returns, which they upload to a higher level mainframe for re-order management. Next, weekly orders are placed to manufacturers of each product sold. In this way, exact quantity replacement is shipped to each individual retail location, through a central distribution center (Automatic I.D. News, July 1995). Any company that does not come on line with bar-coding technology

will soon lose the ability to perform such basic transactions. Companies that are using bar-code technology attain many benefits. With advance knowledge of shipments in transit and of retail store demands, distribution facilities can schedule transportation, receive shipments from suppliers, break them down and route the pieces to the appropriate stores, without stopping the movement of goods. This eliminates handling and storage and related costs at the distribution center. Instead of using inventory as a massive, costly safety stock, firms use information from bar codes as a key ingredient to connecting supply with demand (Automatic I.D. News, July 1995).

A disadvantage of bar-coding is the limited data storage capacity of a bar code. However, 2D bar-codes that have more storage capacity are gaining popularity. Venture Development Corp. claims that by the year 2000 global use of 2D bar-codes will increase tenfold (Lipp, 1996). This, of course, will require a concurrent increase in the capability to read 2D bar-codes.

RF for Cross-docking

Radio frequency technologies are key elements in providing effective, real-time data collection systems crucial to the successful distribution center (Moore, 1994). Supply chain management linked with RF-based automatic data collection (ADC) technologies is moving merchandise through distribution on one day's notice (Navas, 1995).

There are many instances of companies beginning to take full advantage of RF technology to improve their operations. Foxfire Technologies Corp. in Atlanta,GA,

works with its clients in the apparel and textile industries to implement real-time distribution control systems such as wireless RF technology (Moore, 1994). Wireless RF differs from radio receiving in that a scanner is built into a portable unit (a computer with a radio) that can be carried around the distribution center, providing real-time two-way communication. Incoming cases of goods can be scanned by personnel, and the computer can tell the people what to do with the cases. Still, most replenishment going on these days involves walking the floor, scanning shelf labels, and keying in numbers (Navas, 1995).

Even using battery-powered batch data collection is just collecting information, not having an immediate discussion with the computer. Using the RF real-time system, the person who picks up a pallet or case can be directed where to put it and generally cannot continue until he or she properly places the item, thus greatly eliminating errors. Such a system increases inventory accuracy from 90% to 99.9% (Moore, 1994). Some merchandisers have learned how to move products through the distribution center rapidly by using cross docking and real-time RF based ADC technologies. However, only 5 to 10 percent of grocery and retail companies are using cutting-edge logistics initiatives, particularly related to information technology, to save time and money in the distribution center (Navas, 1995). By processing ADC data and asking suppliers to fulfill according to demand, the time-consuming shelf-inventorying process can be eliminated altogether.

EDI for Cross-docking

EDI is "the direct, application-to-application transmission of business documents such as purchase orders, invoices, and remittance advice" (Sterling Commerce, 1997). Some companies have been using a proprietary form of EDI since the 1960's. But companies are realizing the benefits of a common EDI format that allows them to trade nationally and globally ("EANCOM," 1996).

With pre-labeling and ADC, electronic communication is made easy. Electronic data interchange (EDI) can occur between shippers (vendors), DCs, and receivers. EDI is used by vendors to transmit Advanced Shipping Notices (ASNs) to the party receiving inventories to be cross-docked. These ASNs let the receiving party know what products are coming so they can plan for the arrival and coordinate necessary tasks to accomplish cross-docking (Cooke, 1996:3; "Crossdocking in the 90s," 1995:9). Charles R. Troyer of CSC Consulting says, "It's crucial that the ASN arrive at the receiving location before the truck does." This may take EDI systems that transmit ASNs real-time, rather than in batch processes which are common (Harps, 1996:34).

EDI is an essential component in successful cross-docking ("Compliance Labeling...," 1995:32). Most of the data on commercial paper documents are print outs of computerized data, used to convey information to business partners. Unfortunately, the partner often has to re-key the paper data into another computer system. EDI, however, eliminates much of this paperwork by having a business' computer talk to its trading partner's computer, directly transmitting the data ("EANCOM...," 1996). Without EDI, shipping labels would lose most of their value. Using bar code and EDI technologies in

combination, retail and industrial firms can eliminate the need for re-labeling in the supply pipeline; automate distribution centers; provide input for traceability throughout the pipeline; and standardize shipping labels ("Compliance Labeling...," 1995:32).

Organic computer systems may already serve as a repository for data related to business functions such as inventory management and logistics, and can be used to automate creating, sending, receiving, and processing business documents. "It is commonly accepted that 70 percent of one company's business data output becomes another company's business data input." EDI extracts information from applications and transmits paperless, computer-readable business documents via telephone lines and telecommunications devices. At the receiving end, the data can be fed directly into a trading partner's computer system for immediate, automatic processing (Emmelhainz, 1989).

EDI is not without its quirks. Many companies that use EDI only send information out in batches, to save on transmission costs. But to attain the fastest forms of cross-docking, EDI transactions must become event driven, using real time EDI instead of batch process EDI ("Compliance Labeling...," 1995:32). With batch processing, products may arrive to a cross docking facility before the advance shipping notice, eliminating the value of EDI. Another problem with EDI is the lack of a universal standard for EDI protocol. EDI communication standards are needed for data to be communicated through EDI from one computer to another efficiently, quickly and accurately irrespective of the users' internal hardware and software equipment (Sterling Commerce, 1997).

But EDI also has tremendous benefits. It is estimated that paper-based systems cost manufacturers nearly $100 per order to process, whereas EDI purchase order transactions cost about $2; These savings come from reductions in time, inventory, warehouse space, and transaction purchase order, packing slip, invoice, error detection and mis-shipment resolution costs ("Compliance Labeling...," 1995:33). It increases speed by allowing the communication of large volumes of commercial data in minutes, enabling faster response and greater customer satisfaction. EDI eliminates manual data entry errors, improving data accuracy. According to Jim Meece, chairman of the Chicago based OMI International software company, "ECR assumes EDI." Because cross-docked products are shipped so quickly, "distribution centers must have accurate information so that the proper bills can go to retailers." By turning the warehouse into a switching yard cross docking cuts the time product is held, reduces inventories, handling costs and product damage; and communications technology such as EDI is considered an integral part of cross-docking (Garry, 1993).

WMS for Cross-docking

Warehouse Management Systems (WMS) are needed to integrate the EDI, ASNs, and ADC and the handling of products to facilitate efficient and effective cross-docking. The WMS assists in making plans for coordinating product movement through the cross-docking operation before they arrive. The WMS uses transportation software to coordinate inbound shipment as well as outbound shipments. All WMS functions also rely on the ASN (Cooke, 1996:3; "Crossdocking in the 90s," 1995:11).

Companies today are looking for a way to "systematize" cross docking activity so it can be integrated into a streamlined, total logistical solution, enabling distributors to apply cross docking to a far greater range and volume of products than ever before, and realize greater savings by doing so (Casper, 1995). The major component of successful cross docking that can tie all the other hardware and software components together to do that is a warehouse management systems (WMS) (Schwind, 1996). Eric Peters, western regional manager with engineering consultant Tompkins Associates Inc., says a WMS "...can act as traffic cop in the receiving area, redirecting product to the proper outbound door or staging area, minimizing handling" (Casper, 1995). Great strides in information management technology have produced warehouse management systems software that can control almost every aspect of warehouse operations (Schwind, 1996).

Most new warehouse management software is modular or can be configured by the user and adapted to changing situations. There are dock door management programs available that schedule motor carriers from the time they check in at the front gate of a distribution complex to the time the leave. There are also dock position control programs that make sure the carrier is secured to the correct dock before the door is opened. Some programs can even operate the door, the warehouse heaters by the door, the dock leveler to ease loading and unloading, a truck leveler to do the same, and lights or warning signals when needed (Schwind, 1996).

People for Cross-docking

There is one more aspect firms often forget when attempting something new—people. Modern cross-docking must have the support of the people it takes to get the job done (Andel, 1994). None of the components of information technology will work without people who know how to use them and understand how to apply them effectively to meet corporate goals. People are as much a component of information technology as any piece of software or hardware on the market (Scott, 1997). Cross-docking requires coordination, communication, and information sharing. Distributors and retailers must work together to coordinate such responsibilities as case-labeling (Harrington, 1993).

No model in the working world is complete without people. Two major factors involving people are information technology education and solid interrelational skills. Goetschalckx, Associate Professor in the School of Industrial and Systems Engineering at the Georgia Institute of Technology, emphasizes the importance of having a technological degree in the logistics career field. He notes only corporations that empower their employees with information technology education will achieve and maintain logistics proficiency. He says, "We cannot afford a semiliterate work force in the age of satellite communications and real time tracking of materials and transportation resources" (Goetschalckx, 1993).

In addition to technical knowledge and skills, people have to be able to work and communicate with people. According to Jim Gilmore, partner CSC, Cleveland, OH, "Most warehouse managers stay managers because they are good at managing four walls. They should look beyond that" (Loudin, 1995). Cross-docking takes high technology

equipment and software, and persistent cooperation with supply channel partners. People are the glue that make it all stick together to achieve success in such complex endeavors as high-tech cross-docking.

Challenges of Crossdocking

Besides all the information technology systems that may be needed for a successful cross-docking operation, there are other costs and challenges to consider.

Capital Requirements for Cross-docking

In its simplest form, cross-docking can be achieved with a worker and a pallet jack to move products from inbound to outbound trucks. However, capital requirements are dictated by the type of cross-docking performed (current or future) and the cross-docking strategy employed (simple or complex) as well as the characteristics of products being cross-docked. Studies must be accomplished to determine if the products are high moving, light items or heavy, dense, slow moving products, or a mix.

Small, light-weight, pre-labeled products would require conveyors that automatically sort and move products through the cross-dock facility, for the most advanced forms of cross-docking. On the other hand, heavy or odd-sized products would require heavy lifting equipment. An analysis of inventories is essential, to determine characteristics of the predominating product handled, to facilitate choosing the correct capital investments (Cooke, 1996:4; "Crossdocking in the 90s," 1995:14).

"Current cross-docking" focuses on moving products directly from inbound trucks to outbound trucks. This requires little storage or staging area. "Future cross-docking," on the other hand, requires more space for storage and staging because products sit awhile to be consolidated and shipped in the near future ("Crossdocking in the 90s," 1995:14).

Costs of Cross-docking

Capital requirements need to be carefully considered to prevent purchasing and installing expensive equipment only to find the proper information systems to make it work do not exist. Unfortunately, the costs of high-tech cross docking may be prohibitive. Eric Peters, a vice president with the consulting firm Tompkins Associates Inc. of Raleigh, N.C., notes that the necessary equipment for a retail cross docking operation can cost $500,000 or more, yet without computers and automatic identification technology major cross-docking is at best difficult (Cooke, 1996).

One estimate places of the costs for computer hardware and software for a WMS at between $2,800 and $13,500, depending upon the requirements and size of the operation ("Compliance Labeling...", 1995:32).

Other Challenges

Even if a company can afford all the high tech gadgets there can be problems with cross-docking. The greatest operating risk involved in this system is stock outs. In such a low-inventory distribution system, if a glitch occurs, a stock out is likely. Cross

docking works best with short replenishment lead times, fairly heavy demand, and relatively predictable volumes and flows (Harrington, 1993).

Another challenge of cross-docking is data inaccuracy and the need for cooperation between channel partners (Bonney, 1994). A key concept in cross-docking is the exchange of information for inventory. By knowing exactly when products will arrive, in what quantities, and the destination of each package or pallet, a distribution center can employ the cross-docking strategy of immediately moving incoming goods from receiving to shipping. This cannot occur if the distribution center does not have reliable channel partners consistently sending them reliable data in the form of advanced shipping notices (ASN).

Cross-docking may simply not be right for a particular situation, and it is up to managers to know whether or not this is the case. One power tool manufacturer decided to incorporate cross-docking at several of their production plants. According to Bill Devos, senior associate with Austin Consulting, the distribution required by this company did not merit cross-docking the way the company was structured, and they wound up adding three days to their distribution cycle. They made the mistake of trying to force cross-docking methodology onto their people and procedures (Andel, 1994).

Benefits of Cross-docking

Despite the requirements, costs, and challenges of modern cross-docking, commercial firms are benefiting from it. Cross-docking has been around for many

decades ("Cutting Costs with Crossdocking", 1995). It is only recently being emphasized so greatly because information technology has increased the benefits of cross docking significantly enough to gain widespread attention. Today's cross-docking takes standard information systems technology and applies it to intelligently to the business of moving products through a warehouse. According to Virginia Carmon, manager with consultant KPMG Peat Marwick in Dallas, TX, cross docking can cut the overall cost of putting each case of material through a distribution center by as much as 21 to 29 cents ("Crossdocking in the '90s," 1995).

Cross-docking may improve flow through a distribution center if it is done right (Harps, 1996:36). The results of improved flow can mean tremendous time and cost savings. Non-Stop Logistics Corp., a San-Francisco based company, claims that it can significantly reduce retail distribution costs with the use of a cross-docking network of distribution centers. They claim that their cross-docking distribution system will allow manufacturers to reduce inventories in the supply chain by 30-50 percent. They further claim that overall distribution costs can be reduced by 20 to 40 percent with cross-docking (Bonney, 1994:63).

An ECR Joint Industry Report on cross-docking determined that using cross-docking could save retailers or wholesalers from 21 to 30 cents per case. When one considers that a pallet holds tens of cases and a DC can handle thousands of pallets per day, the money savings add up quickly (Casper, 1995:34). Virginia Carmon of KPMG Peat Marwick LLP stated that cross-docking, with effective use of EDI and ASNs, can reduce handling costs by 25 to 45 percent (Casper, 1995:36).

Cross-docking lessens the need to warehouse goods, cuts shipping and receiving errors, enables faster replenishment, helps retailers quickly fulfill catalog orders, and lets buyers obtain larger orders at better prices (Kenedy, 1995). In today's fast paced retail environment, cross docking has become a critical component to achieve continuous replenishment (Cooke, 1996). Cross-docking eliminates unnecessary handling, allows for increased inventory turns, less storage and associated carrying costs, overall lower logistics costs, and provides improved accuracy for better customer service and better business/partner relationships (Garry, 1993:107; Casper, 1994:25; Casper, 1995:34).

The seamless, integrated information flow required for high-tech cross-docking provides product tracking accuracy and service. Delphi Packard Electric Systems, a manufacturer of automobile wiring harnesses, built a new DC based on cross-docking. Delphi has observed incredible accuracy and has provided excellent customer service to its JIT manufacturing customers. With added receiving and shipping doors, new WMS software, and efficient use of its DC space, Delphi immediately cross-docks 75% of its arriving loads and moves 99% of all products out of the DC within 24 hours of receiving it. In 1994, Delphi observed only two errors out of the hundreds of thousands of containers it shipped out that year (Auguston, 1995:38).

Section Three

Introduction to Activity-Based Costing (ABC)

In reaction to changing environments and increasing competition, private sector organizations have been required to find new methods to reduce costs and increase performance in order to survive and succeed. Reduction of costs is essential to maintain competitiveness and cost information happens to be one of the primary weapons that organizations can use in the struggle for survival and success in today's business environment (Compton, 1996:20). The mating of accurate cost information with an effective cost management system that produces intense pressures to reduce costs is essential (Cooper, 1996:26). However, traditional cost accounting systems, still used in businesses today, have been found to be inadequate and unreliable (Harr, 1991:24). Traditional accounting systems have begun to lead managers awry, giving them distorted views of true costs and leading to poorly informed decisions. Activity-Based Costing (ABC) was designed in attempts to alleviate these errors ("Cost Reduction…," 1995:10), giving managers more accurate cost information for better strategic decision making and more relevant cost information for better management of business activities (Beaujon and Singhal, 1990:51; Cooper and Kaplan, 1992:2). As one of private sector's best practices, ABC could be used by government organizations in their efforts to more efficiently manage their activities, and use of resources, and ABC could provide a means for

managers to better understand the costs associated with reengineering efforts, such as implementing cross-docking into a DoD distribution center.

Overview

This second section of Chapter Two provides a literature review on several Acivity-Based Costing issues. Part One discusses the purpose of cost accounting and Part Two discusses how traditional cost accounting has begun to fail in its methods to produce managers with relevant cost information for managing their organizations and activities. Part Three discusses how leading businesses have begun to look toward Activity-Based Costing as a better costing method which provides cost information that is more relevant for managers. Part Four of this section defines Activity-Based Costing (ABC) and Part Five presents the general ABC concept. Part Six outlines ABC's method of providing improved information that enables better management of activities. ABC was originally developed for analyzing manufacturing operations, but has been increasingly used as a costing method for service functions, including logistics. Part Seven describes ABC's applicability in service functions, including the logistics supply chain functions of distribution centers, is discussed. Next, Part Eight discusses the need for improved management practices, especially cost accounting, within government organizations and reviews ABC's applicability within government organizations, including DoD (DoD) organizations. Finally, Part Nine outlines a general methodology of implementing ABC within DoD organizations.

Purpose of Cost Accounting

To get familiar with the terminology, a cost is defined as a resource sacrificed, consumed, or used to achieve a specific objective. Therefore, to guide decisions on alternatives, managers need to know costs and, specifically, need to know the cost of something-a cost object. A cost object can be specified as anything for which a separate measurement of cost is desired. Cost objects are chosen in response for specific decisions to be made (Horngren and others, 1994:26). Examples of cost objects include products, services, customers, a department, or even an activity.

The ultimate intent of costing systems is to report accurate cost information that reflects the way in which particular cost objects (products and services) use the resources in an organization. This information then plays a critical role in supporting managers' efforts to make correct decisions and to reduce costs. Cost information enhances management decisions by helping managers determine which products, services, or customers the business should emphasize and what selling price should be charged for particular products or services (Horngren and others, 1994:98). Cost information also assists managers in their cost management efforts to satisfy customers while continuously reducing and controlling costs, especially when considering implementing reengineering efforts which require investments in new equipment and procedures (Horngren and others, 1994:4-5).

The success of cost accounting directly depends on whether mangers' decisions are improved by the information provided to them (Horngren and others, 1994:3). More accurate and relevant cost information is essential for managers to effectively and

efficiently manage their organizations, allowing their organizations to compete and succeed in an increasingly competitive environment (Compton, 1996:20; Cooper, 1996:26; Harr, 1991:23).

Failings of Traditional Cost Accounting Systems

This section discusses the main failings of traditional cost accounting systems, for they are not adequately meeting the needs of managers. Traditional systems mislead managers by distorting costs, and traditional systems do not provide relevant information for managers to manage their activities in the most effective and efficient ways possible.

Cost Distortion with Traditional Cost Accounting

Managers need accurate product costs in order to make sensible strategic decisions about product design, introduction, support, discontinuance, and pricing. If the cost information is distorted, a firm can follow the wrong and unprofitable strategy (Cooper and Kaplan. 1988:20). Interestingly, recent research has focused on the inadequacies of traditional cost accounting systems. In particular the research has argued that traditional cost systems are not able to report product costs to a reasonable level of accuracy (Cooper, 1990:33) and, as a result, these systems systematically distort product costs (Beaujon and Singhal, 1990:51).

The source of product cost distortion is attributed to traditional cost accounting's choice of a single volume-related allocation base, such as direct labor hours (Cooper,

1988:46). Direct labor hours may have been an appropriate allocation base several decades ago when direct labor was the principle value-adding activity in manufacturing, but today's manufacturing environment is much different (Cooper and Kaplan, 1988:22). Today, product costs contain a much smaller content of direct labor and a much higher content of overhead. With introductions of automation, computer-aided design (CAD), and manufacturing resource planning (MRPII), overhead now represents a much higher percentage of total costs. Traditional cost systems falsely allocate large amounts of overhead with the smallest component of cost (direct labor). In the United States, the average direct labor content of product cost is only 7% (Williamson, 1996:28). Cooper emphasizes that a volume-related allocation base, used alone, can distort product costs when product diversity is entered into the production mix. Production volume, size, material, and setup diversity varies among different products. This diversity means that different products consume resources differently and not always in proportion to volume. A single volume-related allocation base will not recognize the different ways in which diverse products demand resources (Cooper, 1988:53). This is essentially what is known as "peanut-butter costing."

"Peanut-butter costing" describes a costing approach that uniformly spreads the cost of resources to cost objects (products or services provided) when those particular cost objects actually consume resources in a non-uniform way. This leads to undercosting of some products and services and overcosting of others. Over and undercosting can be dangerous because companies that undercost products or services may accidentally accept sales that are actually losses and unprofitable. On the other

hand, companies that overcost products and services are also risking themselves by potentially allowing competitors to enter the market and steal market share. "Peanut-butter costing" occurs when a single volume-related allocation base (direct labor hours) uniformly spreads cost across diverse products or services. This assumes that diverse products and services demand resources in the same way when, actually, their demands on resources differ considerably (Horngren and others, 1994:114). Cooper states, "The types of product diversity that lead to bias in the product costs reported by a volume-based cost system are numerous and common and can be removed only through use of an activity-based cost system" (Cooper, 1988:53).

Inability to Manage Activities with Traditional Cost Accounting

Beaujon and Singhal state that accurately determining product cost is certainly justified. Accurate product cost is essential to making relevant strategic decisions, such as pricing decisions, make-or-buy decisions, and decisions about adding or cutting product lines. However, they state that managers often focus their attention on managing the activities in an organization rather than simply managing a set of products. Management of organizational activities puts focus on eliminating activities that add little or no value and seeks to replace inefficient activities with new processes and new technologies to make those activities more efficient. Traditional cost systems do not adequately assist managers in their efforts to manage their activities and their resulting costs because the level of detail is not right (Beaujon and Singhal, 1990:51).

With traditional accounting systems, managers evaluate performance using reports generated from a general ledger. Peter Zampedro, a director of Advanced Management Programs for the Consortium for Advanced Manufacturing - International (CAM-I), stated that general ledger reports, from traditional accounting systems, are only able to describe what is being spent, not how it is being spent. Zampedro continues that when managers look at monthly figures, they see figures that look either good or bad. These figures do not measure performance and, thus, managers are not informed as to why the costs are either going up or down (Dysart, 1995:30-31). Cooper and Kaplan discuss the traditional cost accounting's method of comparing actual expenses to budgeted expenses. Comparison of actual expenses with budgeted expenses, account by account, is only good enough to provide managers feedback. However, this comparison does not provide managers any reasons why some expenses matched budgets or not (Cooper and Kaplan, 1992:6). Cooper and Kaplan quoted one manufacturing manager as saying,

> Monthly, I do look at the financial reports. ...I look closely at my fixed expenses and compare these to the budgets, especially on discretionary items like travel and maintenance. I also watch a headcount. But the financial systems still don't tell me where I am wasting my money. I expect that if I make operating improvements, costs should go down, but I don't worry about the linkage too much. The organizational dynamics (traditional) make it difficult to link cause and effect precisely. (Cooper and Kaplan, 1992:6)

Cooper and Kaplan argue managers who try to manage from the income statement or balance sheet cannot control their expenses. Managing at this aggregate level will not help managers improve cost figures in future periods. The only way to effectively

manage expenses is to understand how resources are consumed by activities. This requires an understanding of costs at a micro level (Cooper and Kaplan, 1991:131).

Activity-Based Costing (ABC) has been touted as an accounting system that will provide managers with relevant information by providing links between performance of organizational activities and expenses (Dysart, 1995:30). With the information provided by ABC, managers are able to better understand how costs are affected by organizational activities, enabling managers to manage their activities and make decisions that will maintain organizational effectiveness while reducing costs (Cooper and Kaplan, 1992:10). This happens because ABC reveals the links between activities and the demands that activities place on resources, giving managers a micro-level understanding of how products or services consume resources (Cooper and Kaplan, 1991:130).

Movement Toward Activity-Based Costing (ABC)

Many organizations have recognized the need to refine their current costing systems and have considered Activity-Based Costing (ABC) as an alternative. ABC focuses on activities as the fundamental cost objects rather than products or services. Traditional costing systems, however, are not tailored to cost organizational activities (Horngren and others, 1994:115).

A 1987 Consortium for Advanced Manufacturing - International (CAM-I) sponsored study by Howell, Brown, Soucy, and Seed sought to assess managers' satisfaction with their traditional cost accounting information. With respect to traditional

accounting's ability to provide cost and performance measurement information, the study found that about 60% of manager responses were either dissatisfied or felt that their traditional cost information needed improvement (Swenson and Flesher, 1996:49).

Swenson and Flesher decided to conduct a follow-on study, using the same criteria and methodology, to evaluate managers' satisfaction with cost information provided by an ABC system. Swenson and Flesher reported that of 25 firms that had implemented ABC, managers had significantly higher satisfaction with their ABC costing and performance measurement information than with previous traditional systems. Interestingly, out of the 25 firms studied, 23 firms primarily used ABC cost information in their activity management and process improvement efforts (Swenson and Flesher, 1996:51-53). Activity-Based Costing is a better approach for providing managers with relevant information (Beaujon and Singhal, 1990:59). The following section provides a definition of ABC and a quick description on how it works.

Definition of ABC

The *Consortium for Advanced Manufacturing - International (CAM-I) Glossary* defines Activity-Based Costing as follows:

> Activity-Based Costing is a methodology that measures the cost and performance of activities, resources, and cost objects, assigns resources to activities and activities to cost objects based on their use, and recognizes the causal relationships of cost drivers to activities. (RPM Associates, 1997b:2)

The *CAM-I Glossary* further defines an Activity-Based Costing System as

> A system that maintains and processes financial and operating data in a firm's resources, activities, cost objects, cost drivers and activity performance

measures. It also assigns costs to activities and cost objects. (RPM Associates, 1997b:2)

In the cost assignment process of traditional accounting systems, direct costs are traced to cost objects while indirect costs are allocated to cost objects with a volume-related allocation base, such as direct labor hours (Horngren and others, 1994:27). ABC allocates direct material and labor to products or services in just the same way that traditional systems do. ABC, though, is much more sophisticated in the way it allocates indirect overhead costs to products or services by using a variety of allocation bases-called cost drivers (Williamson, 1996:29). A cost driver is ABC's generalization of an allocation base; however, it must be emphasized that cost drivers are not devices to allocate costs. Cost drivers actually represent the demands that outputs make on each activity (Cooper and Kaplan, 1992:4).

ABC starts by identifying the resources and activities that are used to generate the outputs of products and services. The quantities and costs of both resources and activities, needed to produce certain outputs, are calculated. As stated above, the demands that each unit of output places upon an activity is called a cost driver. The cost driver is then used to calculate the cost of each activity. This cost is traced to the product or service by determining how many units of output consumed each activity during any given period of time. Thus, ABC focuses on the activities required to produce each product or to provide each service based on each product's or service's consumption of the activities (Institute of Management Accountants, 1993:2).

Kee further defines ABC with two separate aspects. First, ABC traces indirect costs to cost objects (products or services) on the basis of cost drivers that correlate or have a high cause-and-effect relationship with indirect costs. Use of these multiple cost drivers results in more accurate product costs because diverse products consume resources in different ways. Second, ABC traces indirect costs on the basis of the hierarchical levels at which costs are incurred. This means that indirect costs are consumed at differing levels, such as product, batch, and facility levels. Overall, the use of multiple cost drivers and tracing of costs at different levels, enables ABC to more accurately mimic actual relationships in the production environment. Therefore, ABC gives better estimates of product costs than traditional accounting systems and, furthermore, ABC also provides costs of individual activities (Kee, 1995:49).

ABC Concept

To provide a better conceptual view of how ABC works, the two dimensions of ABC (Figure 1) and the basic ABC model (Figure 2) will be described. The ABC concept provides two dimensions. Each dimension represents a different view. The vertical dimension represents the classic two-stage cost assignment view and the horizontal dimension represents the process view (RPM Associates, 1997c:1)

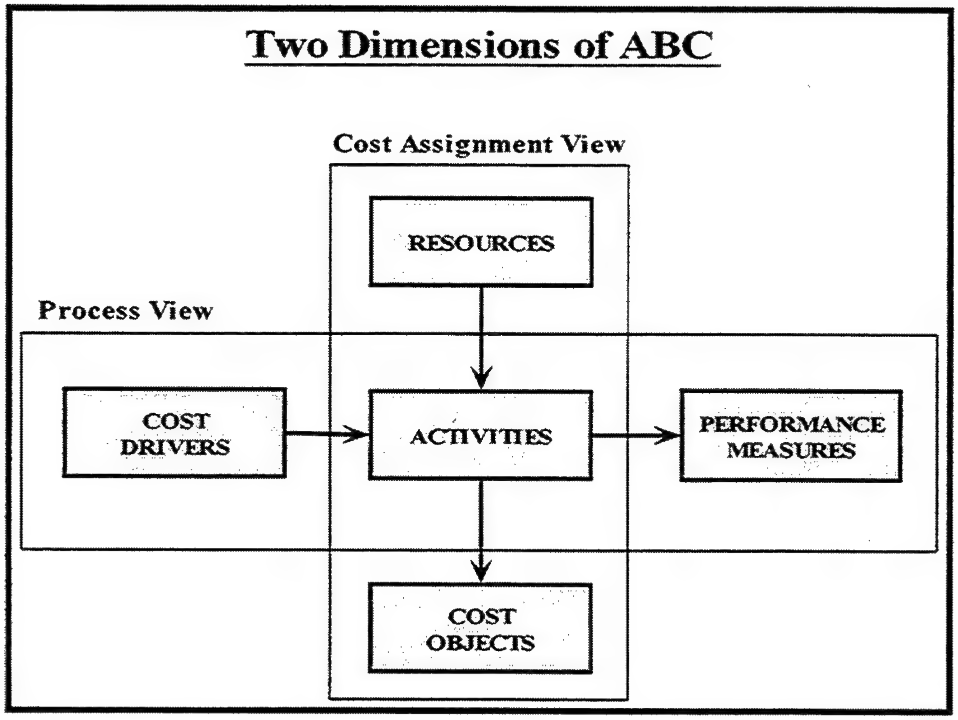

Figure 1: Two Dimesions of ABC (RPM Associates, 1997c:2)

The cost assignment view contains the structure and tools which are used to trace and allocate resource costs to the activity. The resource block contains all of the resources that an activity can draw from when work in an activity is performed. Resource cost drivers are then developed and used to assign resource costs to the activities. This is the first stage of an ABC model. When an activity performs work, the resources are then converted to some type of output, such as a product or service. In this second stage, activity cost drivers are developed and used to assign costs of resources, used by the activity, to the product or service. In this cost assignment view, the activity is only considered as part of the cost structure (RPM Associates, 1997c:1).

The process view provides information about what has been happening. The process view is initiated by the occurrence of a cost driver. The cost driver represents the

demands placed on an activity by a particular output (product or service provided). Thus, the cost driver is what causes the activity to consume resources while it is performing work on an output. In this view, the activity is a considered an entity that performs work rather than part of the cost structure as in the cost assignment view. During the accomplishment of an activity, performance data can be collected. This performance data is used to determine if the activity operated effectively and efficiently during its operation. As opposed to the static nature of the cost assignment view, the process view is dynamic and always changing. Each time a cost driver initiates work within the activity, a new performance measure will be recorded. Accurate tracking of activity performance and use of pertinent performance measures enables managers to monitor activities and to implement process improvement efforts. In this view, ABC helps with process improvement efforts. (RPM Associates, 1997c:1-2)

As already stated, ABC traces costs by using multiple cost drivers and a two-stage process. The first stage assigns resource costs to activities based on the amount that each activity consumes various resources. In the second stage, resource costs, that have been accumulated in each activity, are assigned to the products or services based on the amount that each product or service consumes the activity (Pohlen, Callahan, and Marion, 1995:36). ABC then determines the costs of products or services based on their usage of these activities (Harr, 1991:23). Beaujon and Singhal demonstrate the two-stage cost assignment process that was originated by Cooper (Figure 2). Cooper stated,

> The first stage takes such resources as direct labor and supervision and splits them up into sections, each related to a segment of the production process. These segments can be machines, ...collections of machines, or even entire departments. ...These costs are then traced, in the second stage, from the cost

pool to the product using a measure of the quantity of resources consumed by the product. (Beaujon and Singhal, 1990:52)

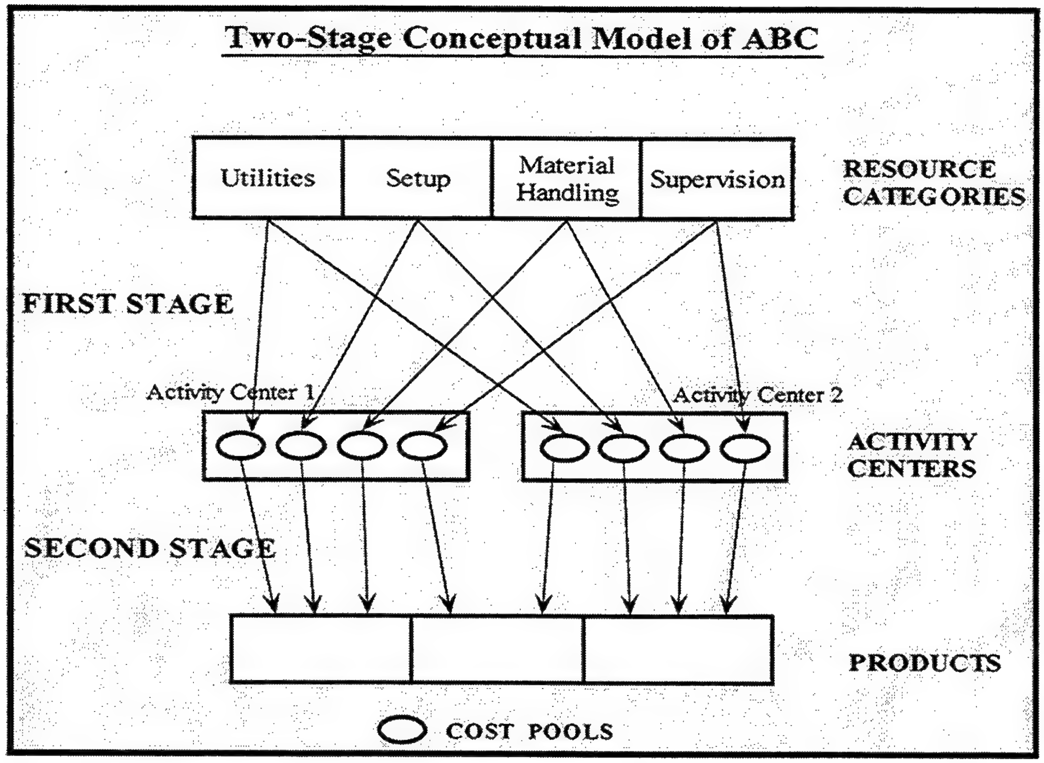

Figure 2: Two-Stage Conceptual Model of ABC (Beajon and Singhal, 1990:53)

Cost pools are generated and used to split up resources among different activities with the use of first stage cost drivers (Beaujon and Singhal, 1990:52). Within each cost pool the costs are homogeneous, or related to the same cost driver (Harr, 1991:24). Then resources, that have been collected in each cost pool, are assigned to product with the use of second stage cost drivers. Activities, or activity centers, are used indirectly in the cost assignment process of products. To reiterate, costs flow from resources to cost pools, within activities, and then to products (Beaujon and Singhal, 1990:54).

Using ABC for Activity Management

As already stated, accurately determining the cost of products is certainly justified since accurate product cost is essential to making relevant strategic decisions. However, managers often focus their attention on managing the activities in an organization rather than simply managing a set of products (Beaujon and Singhal, 1990:51). ABC focuses manager attention on improving activities that have the largest impact on costs and profits, enabling managers to reduce costs and increase profits for a better competitive stance (Cooper and Kaplan, 1991:130). To do this ABC models, first, must be designed to facilitate managers understanding of how activities affect costs in the organization. Second, ABC models must be able to discern the costs of resources used versus resources unused by particular activities. This part on activity management will discuss these two issues.

Understanding Activity Costs

ABC can provide a better understanding of how to reduce costs by managing those activities that consume the resources in an organization because ABC directly associates costs to a manageable set of activities. However, to maximize ABC's contribution to activity management, it is critical to understand how ABC design decisions affect the understanding of the cause-and-effect relationship between costs and activities. In choosing ABC model designs, it is important to choose designs that increase the likelihood that managers will correctly interpret and use ABC cost information. The level of detail in an ABC model, the ease of associating meaningful

costs to activities, and the ability of users to interpret ABC information correctly all must be contemplated by ABC designers in their efforts to facilitate managers' abilities to manage activities (Beaujon and Singhal, 1990:51,52,55). To do this, ABC models should first be designed so that information on activity costs are available in the form of resources, activity centers, and cost drivers. Second, activities must be recognized by class.

Activity centers are considered the "activities" in an ABC system or model while resources, contained in the general ledger, must be split up into activity centers by cost drivers. Thus, choosing appropriate costs drivers is critical in ABC design (Beaujon and Singhal, 1990:56-60). Cooper provides insight on determining how to select appropriate costs drivers. He provides several factors that affect the selection of cost drivers, including:

> *Cost of measuring the cost driver*. The lower the cost, the more likely the cost driver will be selected.
>
> *Correlation of the selected cost driver to the actual consumption.* The higher the correlation, the more likely the cost driver should be used.
>
> *Behavior induced by use of the cost driver.* The more desirable the behavior induced by the driver, the more likely the driver is to be selected . (Cooper, 1989:45)

Cost drivers represent the cause-and-effect relationship between some activity and a set of costs. Cost drivers, therefore, are considered and interpreted as a measure of an activity and costs drivers, when analyzed, are used to suggest which activities are taking place and how much each activity costs (Beaujon and Singhal, 1990:57). These three cost structure items (resources, activity centers, and cost drivers) are appropriately

designed and selected to provide the necessary level of detail, meaningful cost information, and correct cost interpretations for managers to better understand activity costs. This enhances managers' ability to manage their activities (Beaujon and Singhal, 1990:51).

Another issue that affects activity management is that activities must be recognized by type of class they represent. Understanding the classes of activities allows the manager to make relevant decisions for that activity and understand the associated costs in a decision. Classes of activities include:

> *Unit level activities* are performed one for each unit produced.
>
> *Batch-level activities* are performed once for each batch produced and are activities that are common to each unit in the batch.
>
> *Process-level activities* that support the individual process, for example maintenance of equipment and machinery.
>
> *Plant-level activities* that sustain overall operation of the plant, for example plant administration (Beaujon and Singhal, 1990:70).

Appropriate cost drivers must be selected for each class of activity. This leads to a more detailed description of activities and to ABC information that is easier to interpret correctly (Beaujon and Singhal, 1990:70).

Costs of Resources Used vs. Unused

Cooper and Kaplan discuss how ABC models are used to estimate the costs of resources used in organizational activities to produce outputs, such as services or

products. With ABC resource usage cost information, managers are able to pinpoint activities for cost reduction (Cooper and Kaplan, 1992:2).

The measurement of unused capacity provides the link between the costs of resources used and the cost of resources available for each organizational activity considered. ABC measures the costs of resources used while the organizations periodic financial statements provide the cost of resources available. Cooper and Kaplan give the following equation, for each individual activity, to "formalize" this relationship (Cooper and Kaplan, 1992:1):

[Activity Availability = Activity Usage + Unused Capacity]

Traditional cost accounting measures what it costs to "do" a task. ABC measures how much it costs to "do" something, but it also records the cost of "not doing." Traditional cost accounting cannot measure this. This is important because sometimes the cost of "not doing" exceeds the cost of "doing." Therefore ABC not only gives better cost control, but also gives "results control" (Druker, 1995:55-56).

Cooper and Kaplan provide a simple example describing the difference between the cost of resources supplied and the cost of resources used to perform activities. Their example is a follows:

> Consider a purchasing department in which the equivalent of 10 full-time people (the resources supplied) are committed to processing purchase orders (the activity performed). If the monthly cost of a full-time employee is $2,500, the monthly cost of the activity, "Processed Purchase Orders," equals $25,000. Assume that each employee, working at practical capacity, can process 125 purchase orders per month, leading to an estimated cost of $20 for processing each purchase order. Thus, the organization, each month, spends $25,000. This expenditure provides a capability to process up to 1,250 purchase orders (the activity availability) during the month. During any particular month, the department may be asked to produce fewer purchase orders, say only 1,000. At

> an estimated cost of $20/purchase order, the ABC system would assign $20,000 of expenses to the parts and materials ordered by the purchasing department that month. The remaining $5,000 of monthly operating expenses represents the costs of unused capacity in the purchase order processing activity. (Cooper and Kaplan, 1992:2)

Cooper and Kaplan contend that firms must use two costing systems to generate this information. The periodic financial statements provide the cost of activity supplied. ABC provides information on the quantity of and the estimated cost of activities actually used during the period. The difference between costs supplied and costs used equals the cost of unused capacity during the period (Cooper and Kaplan, 1992:3).

Sometimes organizations acquire resources as they are needed, for example materials and temporary labor. However, most organizations acquire resources to be used over future activities. Examples of this are when organizations buy buildings and equipment, incurring expenses over the useful life of the resources. Another example occurs when organizations contract with salaried and hourly employees to maintain employment levels. In both cases, the expense of supplying these resources, and their resulting capacities, will always be incurred no matter if the resources are used or not (Cooper and Kaplan, 1992:5).

To conduct an ABC analysis, one must first identify the cost of resources supplied. Second, the capacity or number of units of service (cost drivers) that can be practically delivered by the supplied resources must be identified. Lastly, the expense of resources supplied is divided by the practical number of units of service performed to get an estimate of the cost of supplying each unit of service of the activity (Cooper and Kaplan, 1992:6).

Cooper and Kaplan provide an example (Figure 3) of an income statement provided by an ABC system. The statement can report, for each individual activity considered, the cost of resources used for outputs and the cost of resources unused during the period. As seen in Figure 3, the cost of resources are not affected by activity levels. In the activity Engineering Changes, demand exceeded the resources available. In response management might want to add more resources in the future, such as another employee, so that demand will not exceed resources availability in the future (Cooper and Kaplan, 1992:6).

Sales			20,000.00
Less: Expenses of Resources Supplied- **AS USED**			
Materials	7,600.00		
Energy	600.00		
Short-term labor	900.00		9,100.00
Contribution Margin			10,900.00
Less: Activity Expenses: **COMMITED RESOURCES**	USED	UNUSED	
Permanent direct labor	1,400.00	200.00	
Machine run-time	3,200.00		
Purchasing	700.00	100.00	
Receiving/Inventory	450.00	50.00	
Production runs	1,000.00	100.00	
Customer Admin	700.00	200.00	
Engineering changes	800.00	(100.00)	
Parts Admin	750.00	150.00	
Total Expenses of COMMITED RESOURCES	9,000.00	700.00	9,700.00
Operating Profit			1,200.00

Figure 3: Example of an ABC Income Statement (Cooper and Kaplan, 1992:7)

With the information provided about unused capacity, managers may want increase the efficiency of resource usage in various activities, thus, increasing

organizational profits. ABC models can help managers in their efforts to reduce resource usage. Reducing demands on resources requires that managers: 1) reduce the number of times an activity is performed; and 2) increase the efficiency in which activities are performed through use of advanced technologies (EDI, Automatic Identification Technology, etc.). Both efforts will reduce resource usage and excess unused capacity will result. If managers choose so, this excess capacity can be reduced in future budgets by selling unneeded machinery, by re-deploying employees to constrained activities, or by laying off unneeded employees. Managers may not want to take these actions, but even though resource usage has reduced, extra capacity has built up. If this extra capacity is not managed away, expenses will remain fixed and cost reductions will not be achieved.

ABC - Not Just for Manufacturing

ABC primarily had it beginnings in manufacturing organizations. Still, little research has been written on how ABC can be used for other company functions, such as logistics (Pirttila and Hauteniemi, 1995:327) and other service-oriented functions. Although service-oriented functions and organizations do not produce assets, upon which stock value must be placed, service organizations can equally benefit from the uses of ABC (Kennedy, 1996:24). Druker believes that ABC could reap its greatest impact in service industries and functions. Service industries, unlike manufacturing, virtually have no cost information at all (Druker, 1995:55). Furthermore, most traditional cost

accounting systems do not address logistics functions. This has serious implications because average companies spend 12 percent of their revenues on logistics activities (Barr, 1996:39).

Just knowing and managing the cost of operations (production) alone does not enable a company to succeed in an extremely competitive environment. To be competitive a company must be able to cost all the functions in the entire economic chain. This allows a company to understand and manage costs all the way from raw material acquisition through delivery to customers and even the costs of providing after-sale service to customers (Druker, 1995:56-57). Costing the entire economic chain enables companies to cost individual functions and enables companies to compare these functional cost as a whole. This allows companies to pinpoint certain functions and make smart choices in cost reduction, avoiding sub-optimization (Barr, 1996:38). Costing the economic chain requires that cost information must be shared across functional boundaries and often requires sharing of information between different companies within the chain. To make sharing of this costing information a reality, the cost information must be uniform and compatible across the entire chain. ABC, used in different chain functions, allows for cost information to be compatible. Thus, ABC can be used to show the impacts of changes in cost across the economic chain (Druker, 1995:56-58).

To maximize overall company profits, it makes good sense to look at costs outside the factory because ABC is extremely applicable across the spectrum of company functions (Cooper and Kaplan, 1991:130). Service industries, such as logistics can benefit from the added information and decision making capabilities that ABC offers

(Pohlen and others, 1995:36). The applicability of ABC in service organizations, such as logistics, is obvious because service function managers face similar critical issues that managers have faced in manufacturing organizations. Several critical issues facing service managers today include: 1) costs are unknown at the present time; 2) there is no rational basis for pricing decisions; 3) what mix of services do we provide; 4) the effectiveness of resources is unknown; 5) how to fit mandated activities within shrinking budget envelopes; and 6) there is no performance measurement framework (Lambert and Whitworth, 1996:24).

Pohlen, Callahan, and Marion provided several reasons for implementing ABC in logistics organizations. They determined that several organizations implemented ABC to: 1) determine the factors that drive logistics costs; 2) assign logistics costs to product divisions; 3) obtain more accurate, or finer, cost data; 4) trace the effect of logistics costs on profitability; 5) target sales/marketing efforts on the most profitable customers, products, or regions; and 6) focus reengineering efforts and costing the resulting benefits (Pohlen and others, 1995:37). They further identified four key benefits that ABC provided to logistics businesses. First, ABC provided more accurate cost information that supported management decision making. Second, ABC provided a better understanding of how activities and outputs consumed overhead resources. Third, ABC prioritized sales and marketing efforts on the most profitable customers while focusing efforts to reduce costs for unprofitable customers. Finally, ABC provided essential information needed to focus managers' attention on areas (activities) where costs could

be reduced, giving the companies a better competitive stance (Pohlen and others, 1995: 38).

One area of logistics that ABC has recently benefited is in the functions of warehousing and distribution centers (Dysart, 1995:30). The growing use of ABC in warehousing and distribution centers has influenced companies toward moving away from traditional warehousing functions. ABC has led companies to gain a holistic cost of their supply chains. This has shifted companies in a direction toward new distribution methods, such as cross-docking (O'Leary, 1996:25). Cross-docking, which places increasing costs closer to the shipper, allows for overall lower distribution costs and better service to customers (Garry, 1993:107; Casper, 1994:25; Casper, 1995:34-). Bruce Westbrook, a partner with the consulting firm Coopers & Lybrand, contends that ABC should be used in a company's overall cost cutting process so they do not make suboptimal choices, especially in distribution. Westbrook states, "...We have seen upward of 15% to 20% savings consistently in projects (distribution) involving ABC. For a grocery chain doing about $2.2 billion in business, we took out $45 million-costs that dropped to the bottom line" (Andel, 1996:88).

ABC has the ability to focus on organization-wide activities. Thus, it is being seen as an essential tool to enable both profit and non-profit service organizations to improve utilization of resources in order to meet performance expectations. Service organizations that can achieve good results from ABC include distribution and logistics firms. This also includes organizations within the government, including the armed forces (Lambert and Whitworth, 1996:24).

Government Cost Accounting

This part on government cost accounting first discusses the similarities between government accounting and traditional cost accounting. Next, the need for better cost accounting practices within government organizations is outlined. Finally, the applicability of implementing ABC within government organizations is discussed.

Traditional cost systems in the private sector identified costs by functional responsibility centers. Government accounting practices are very similar. Governmental accounting systems identify costs as they occur in individual organizational elements. Furthermore, governmental accounting only determines the costs of functional categories rather than determining the costs of cost objects, such as products and services, as is done in traditional private sector cost accounting (Harr, 1991:23). This governmental accounting method is called fund accounting. Fund accounting is designed to trace congressional appropriations to specific categories of expenditures, providing managers only with visibility of expenditures within specific levels of government and by specific categories of expense (Callahan, Marion, and Pohlen, 1994:37).

The fund structure of the DoD (DoD) is described below. The DoD management control structure is called the Future Years Defense Program (FYDP) and the process that changes and updates the FYDP is the Biennial Planning, Programming, and Budgeting System (D'Angelo, 1996). Through the DoD Program Budgeting structure, congressional budgeters are able to review and trace congressional DoD appropriations to distinct levels of indenture. These different levels are composed of DoD's major force

programs all the way down to individual unit-level categories of expense (Callahan, Marion, and Pohlen, 1994:37).

Eleven major force programs (MFP) make up the broadest categories of expenditure in DoD. The eleven MFPs are consist of seven force related programs (e.g., Strategic Forces) while the remaining four are support related programs (e.g., Training and Administration) (D'Angelo, 1996). Within each MFP, there are several program element codes (PEC) which are organizations that are combined to constitute a MFP (Callahan, Marion, and Pohlen, 1994:37). For example, within MFP Four (Airlift/Sealift), there would consist of a C-5 Program Element, a C-17 Program Element, etc. (D'Angelo, 1996).

At the unit level, the DoD appropriations are classified with a single program and its related mission. This form of budgeting is called Object Classification Budgeting. This identifies expenditures by categories of expense. These categories of expense are formally known as element of expense investment codes (EEIC). Examples of these unit-level EEICs are travel, equipment repair, personal equipment, etc. (Callahan, Marion, and Pohlen, 1994:37).

Consideration must be given to another level in the DoD fund and budgeting structure. This level represents the responsibility center/cost center (RC/CC). At this level, the responsibility center is an organization headed by a financial manager responsible for managing the money allocated to EEICs through Object Classification Budgeting (Callahan, Marion, and Pohlen, 1994:37). Each RC/CC is recognized as an

input of money only and offers no monetary measure of output (D'Angelo, 1996). Figure 4 presents the DoD's Program Budgeting structure.

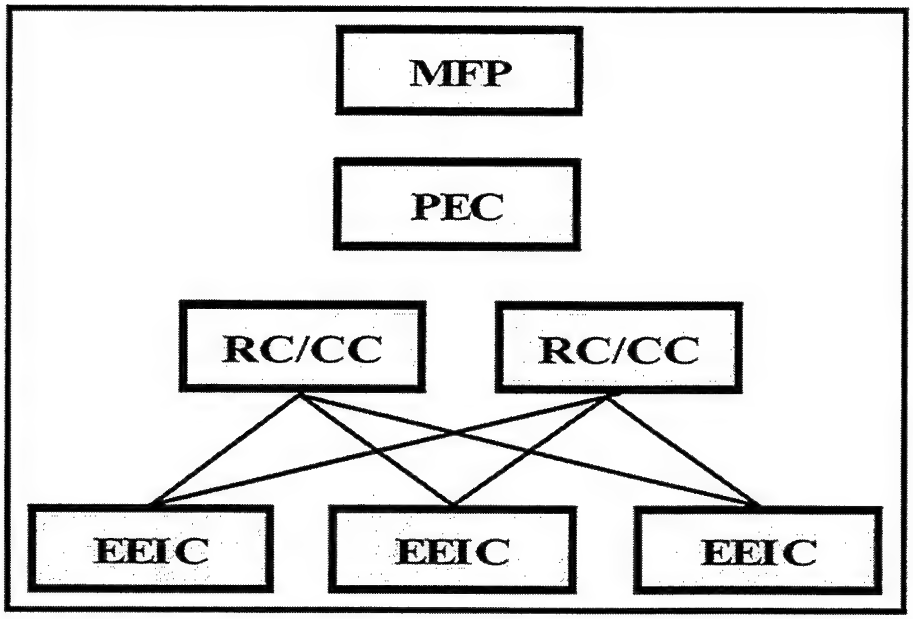

Figure 4: Object Classification Budgeting (Callahan, Marion, and Pohlen, 1994:37)

As a result of this type of budgeting system, costs are traced only to each EEIC. This Object Classification Budgeting does not link organization performance to it budgets nor does it link organizational costs to its activities (Callahan, Marion, and Pohlen, 1994:37). In this way, governmental cost accounting closely resembles traditional costs accounting systems in the private sector. Cost are only identified by how costs are incurred by function, not by how costs are incurred by providing a particular product or service (Harr, 1991:23).

The need for better cost accounting practices in government organizations has been strongly suggested by Mr. Bowsher, Comptroller General, in several scathing

reports. In 1985, Comptroller General Bowsher highlighted the importance of accounting in correcting inefficient government management. At the top of his GAO (GAO) report's list of government management problems was that cost data was unreliable, inconsistent, and irrelevant. In 1989, the GAO, headed by Bowsher, concluded that previous efforts to improve internal controls were unsuccessful. The report (GAO/AFMD-90-10) stated that the government remained "unable to manage its programs, protect its assets, or provide taxpayers with the effective and economical services they expect and deserve." In testimony to the House of Representatives in 1990, Comptroller General Bowsher called for a sense of urgency in correcting the internal control and cost accounting problems that have plagued governmental organizations for such a long time (Geiger, 1995:48-49). Finally, in a 1993 report to Congress, Bowsher stated,

> Over the past decade, many private sector organizations recognized that they would have to change their cultures and processes to survive...The federal government is obviously not going out of business, but its ability and capacity to serve the public have clearly diminished. We must change the way we manage the government if we are to improve its efficiency and effectiveness and restore public confidence. (Geiger, 1995:49)

It seems that these remarks might have had an impact. Over several years, the government has enacted several mandates that have called for improvements in government managerial cost accounting. These are: 1) The Chief Financial Officers (CFO) Act; 2) the Government Performance and Results Act; 3) the Government Management Reform Act; 4) the National Performance Review; and 5) the creation of the Federal Accounting Standards Advisory Board (Geiger, 1995: 49).

Both the Chief Financial Officers Act of 1990 and the Government Performance and Results Act of 1993 emphasize that government cost accounting systems need to be

replaced or supplemented. Government accounting systems need to be changed to support managers by providing managers with cost information that will enable managers to measure, manage, and improve activities and processes (Callahan, Marion, and Pohlen, 1994:36). The Government Management Reform Act expanded the coverage of the CFO Act, calling for innovative approaches to reducing costs and increasing efficiency in government organizations (Geiger, 1995:50-51). The National Performance Review was issued to "reinvent" federal management processes. President Clinton, when announcing the Review, stated,

> Our goal is to make the entire federal government both less expensive and more efficient, and to change the culture of our national bureaucracy away from complacency and entitlement toward initiative and empowerment. We intend to redesign, to reinvent, to reinvigorate the entire national government. (Geiger, 1995:51)

Finally, the Federal Accounting Standards Board was created to set cost accounting standards as requested by the National Performance Review. The Board's goal is to make federal cost accounting realize improved operating performance, budget integrity, stewardship, and deterrence of waste, fraud, and abuse. The Board seeks to meet these goals through recognition of the "full cost of outputs" (Geiger, 1995:51). Interestingly, ABC was designed to give managers the cost of outputs by determining the cost associated with providing a certain product or service (Callahan, Marion, and Pohlen, 1994:36). Knowing the limitations that traditional accounting systems have imposed on private sector organizations and the movement of private sector toward use of ABC, government organizations, specifically DoD distribution centers, in their need to better

manage activities with better cost information, might find that ABC will pose a viable cost accounting alternative for government organizations to implement.

In their award winning research, Callahan and Marion determined that ABC was an applicable cost accounting methodology for DoD service organizations. In their research, they found that: 1) an ABC system can be used to determine costs of activities within a government service organization; 2) a government service organization that implements an ABC system will realize differences in cost visibility of activity and process costs; 3) DoD managers are able to use information provided by an ABC system to determine activity and process costs, as well as resource allocation; 4) government accounting systems do not link budget expenditures to costs of activities or processes; and 5) corporate ABC implementation procedures were able to implement an ABC cost model within a DoD service organization (Callahan and Marion, 1994: 106-123).

Methodology to Implement ABC in a DoD Service Organization

Callahan, Marion, and Pohlen provide a general four-step process for developing an ABC model for DoD service organizations (see Figure 5). The ABC system traces expenditures across EEICs to the activities and services of a DoD organization.

Step 1 surfaces key issues that should be addressed by managers before implementing an Activity-Based Costing model. Managers are the primary users of ABC information, thus, they should be consulted on what types of information they want the ABC model to provide. The key issues to address with managers are: 1) what is the

purpose of the model; 2) what level of detail is required in the model; 3) what organizational costs will the model consider; and 4) how will the model be constructed and maintained (Callahan, Marion, and Pohlen, 1994:38)?

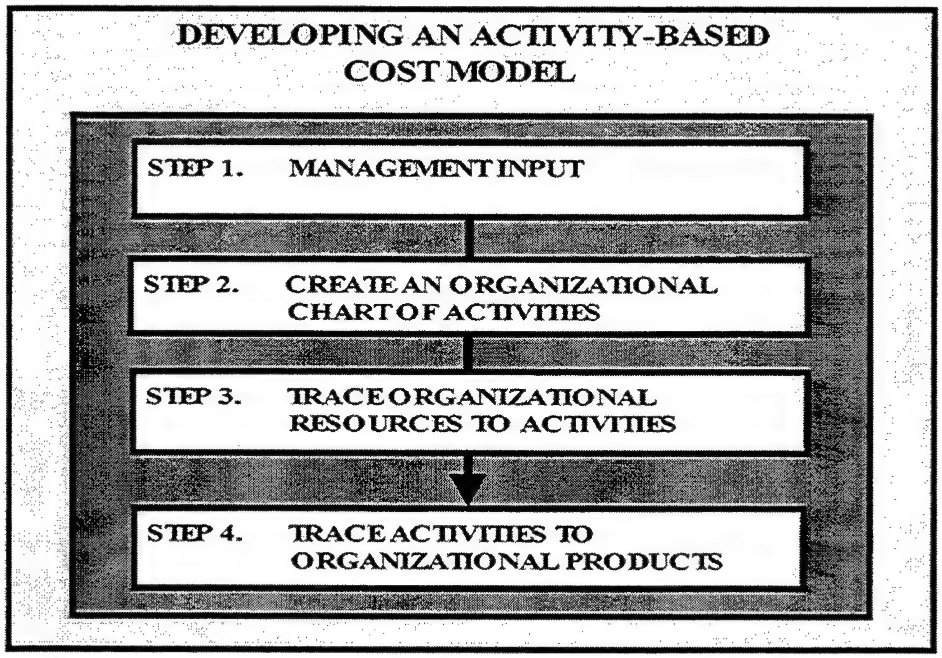

Figure 5: Developing an ABC Model (Callahan, Marion, and Pohlen, 1994:40)

Step 2 outlines the need to create an organizational chart of activities. This is best done by analyzing key processes first. Processes are composes of various activities. Thus, it is simpler to start at a macro level with processes and work down to specific activities, gathering a higher level of detail (Callahan, Marion, and Pohlen, 1994:40).

Step 3 outlines the need to trace organizational resource to activities (see Figure 6). Government accounting systems track resource usage from individual expensed categories, EEICs. These EEICs trace costs downward into an organization's individual

departments. A problem arises from doing this because organizational activities and activity costs, in reality, cut horizontally across departments, not by functional department. Tracing of EEC's to organizational activities, rather than individual departments, allows costs to be cut horizontally through departments and reflect the true nature of how costs are incurred (Callahan, Marion, and Pohlen, 1990:40).

Step 4 outlines the need to trace costs of activities to organizational products and services by use of appropriate cost drivers (Callahan, Marion, and Pohlen, 1994:40).

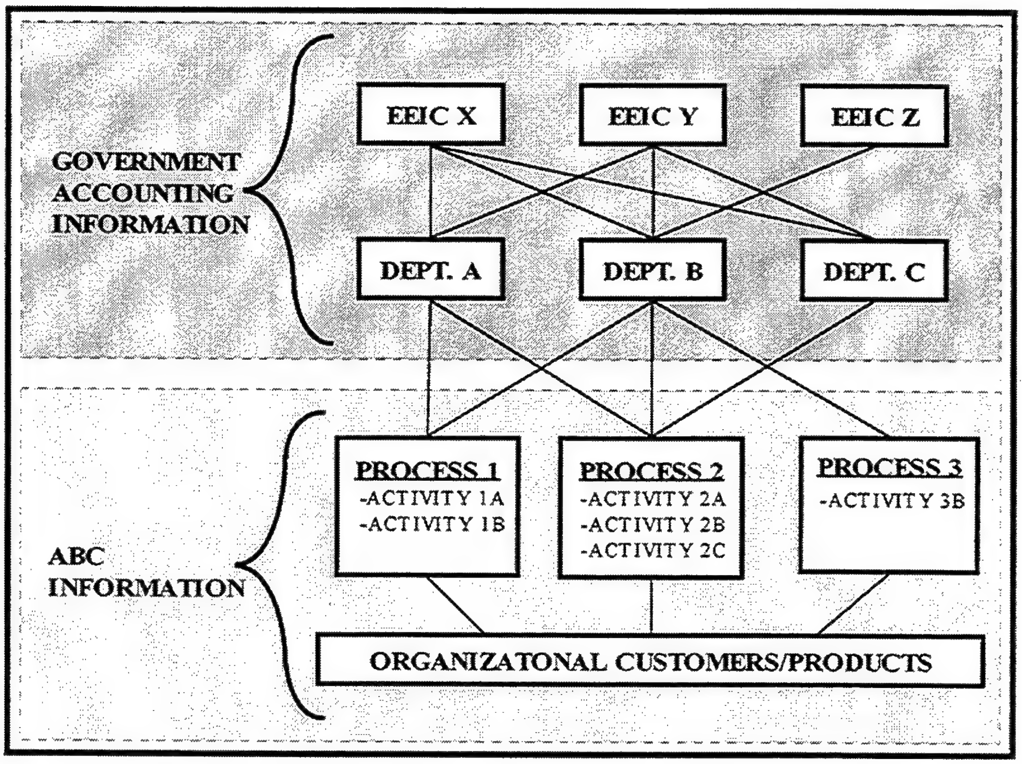

Figure 6: Tracing Organizational Resources to Activities

Summary

This section discussed the traditional cost accounting and its general failings in providing managers with relevant cost information for making pricing decisions and for

managing activities, especially where reengineering efforts are considered. A discussion on Activity-Based Costing (ABC) was provided, describing how ABC was a better costing alternative which overcame the limitations encountered with traditional accounting. Even though ABC was introduced and primarily used in manufacturing organizations, ABC has been determined to offer its benefits to other service-oriented organizations, such as logistics organizations and even government organizations. Current governmental cost accounting systems have been identified as being inadequate in providing managers with relevant cost information about their organizational processes and activities, relating government costs accounting to traditional cost accounting in private sector businesses. Research conducted by Callahan and Marion proved ABC could be feasibly implemented into DoD service organizations and provides more relevant cost information to DoD managers. Finally, a methodology, provided by Callahan, Marion, and Pohlen, detailed four major steps necessary for implementing ABC into a DoD organization.

Section Four

Introduction to Computer Simulation Modeling

Accurate analysis of an environment as complex as a distribution center is a tremendous challenge. Computer simulation models are often used as tools to analyze such complex environments (Krajewski and Ritzman, 1996:323). It may be feasible for the DoD to use a computer simulation model to evaluate its military DCs. With the power of today's computers, even the most complex DC operations could be modeled in minute detail, if enough information were collected and incorporated into the model. At the same time, it may be possible to incorporate ABC techniques into a computer simulation model to simultaneously analyze both the time and cost performance of activities within a military DC.

As mentioned earlier, the use of simulation for costing of activities and product cost allocation is an unexplored area in ABC literature (Raghu, Chaudhury, and Rao, 1997:3). However, if a DC were modeled in such a way, programmers could possibly then alter the model to incorporate leading edge cross-docking concepts into the DC, and evaluate the time and cost benefits of doing so. These benefits could then be weighed against the reengineering or modifications costs of such improvements. This simulation model, then, could be used as a decision support tool to help logistics managers improve military DC operations in support of the DoD's logistics goals.

Overview

This fourth section of the literature review provides a basic understanding of the terminology encountered when dealing with computer simulation modeling and discusses its benefits, limitations, and applicability to a logistics distribution center.

Definitions

Using computer simulation to model a real world operation requires a basic understanding of computer simulation and modeling terminology. Below are the basic definitions from computer simulation modeling textbooks that, taken together, may provide such an understanding.

Computer Model

There are many descriptions and synonyms for the term "model." Zeigler and others, provide a more precise definition of a computer model:

> A model, in the computer context, can be viewed as a set of instructions for generating behavior (time sequences of values of variables). As a model of a real system, the models' behavior must be comparable with some behavior of interest in the real system. A computer, under the control of a program which implements to model may be employed to generate the model's behavior. (Zeigler and others, 1979:xii)

Computer Simulation

Computer simulation is a method that can be used to study the performance or behavior of a real-world system. The process of behavior generation is called simulation (Zeigler and others, 1978:xii). First, a computer simulation model that behaves like the real system is developed. The programmer then ensures the simulation model is descriptive of the real system. The through a series of computer runs, or experiments, we learn about the behavior of the simulation model. The characteristics observed in the model are then used to make inferences about the real system. (Anderson and others, 1994:556)

Discrete-Event Simulation

Discrete-event simulation is a subset of computer simulation modeling. Law and Kelton provide the following definition:

> Discrete-event simulation concerns the modeling of a system as it evolves over time by a representation in which the state variable change instantaneously at separate points in time. Although discrete-event simulation could conceptually be done by hand calculations, the amount of data that must be stored and manipulated for most real-world systems dictates that discrete-event simulation be done on a digital computer. (Law and Kelton, 1991:7)

Benefits and Limitations

Like all things, there are advantages and disadvantages to computer simulation modeling. Pegden and others, in 1995 list several pros and cons of computer simulation modeling. Advantages include: Gaining insight without disruption the actual system;

Testing designs without capital outlays; Hypothesis testing; Time compression or expansion; Insight about the interaction of variables and the importance of variables within a system; Bottleneck analysis; "What If" analysis. Disadvantages include: Special training required for modeling; The difficulty of interpreting results; Time and costs involved in simulation; Use of simulation when analytic solutions could have been attained (Banks and others, 1996:5).

Simulation Modeling for Cross-docking

"Computer simulation is one of the most frequently used techniques of management science" (Anderson and others, 1994:556). As business process reengineering efforts move into the logistics area, cross-docking has become very popular in distribution (Rohrer, 1996). Computer simulation imitates the actual operation of a real-world process over a span of time. Specifically, a simulation model is used to study the behavior of a process or system over time. Computer simulation is a unique tool that is well suited for assisting a reengineering effort (Banks, Carson, and Nelson, 1996: 8). Simulation models can analyze the impact of process changes, identify bottlenecks in a system of processes, and can estimate cost implications of reengineering alternatives (Gordon and Gordon, 1996: 377).

Computer simulation modeling can be used to aid logistics managers with distribution strategic planning decisions (Waller, 1995). In today's warehouses, computers are used to manage inventory transactions and to control automated systems.

By tracking inventory transactions, software programs become the means by which the flow of materials in cross docking operations can be managed. These management systems include algorithms that can be modeled in a computer simulation to test cross docking before implementing it (Rohrer, 1996). Using a computer model to perform What-If analyses, engineers and managers see if new systems will work.

Managers considering distribution strategies have all too often only dealt with a single aspect of distribution (Waller, 1995). For cross docking there are several important configuration and control issues that simulation can help resolve, such as: level/location of automation; plans for equipment downtime; queuing requirements; interface with manual handling equipment and personnel; product identification/tracking; resource assignments (Rohrer, 1996). Warehouse managers can see a month's worth of different operating scenarios in a few minutes, helping them make better decisions about operations. If much of the model input data is contained in a few spreadsheets, managers who are unfamiliar with simulation can quickly experiment with different cross docking scenarios. Data, like conveyor downtime, dock assignments, and production rates, could be easily modified in a spreadsheet. The computer model then provides system performance statistics, like equipment utilization, labor requirements, product cycle time, products handled per unit time, and storage area use, that can be used to evaluate alternatives and decide what cross docking set up best meets the business goals. Then modification costs can be weighed against potential benefits (Rohrer, 1996). If at all possible, the first thing an organization should do is run a computer simulation model of their current distribution operations to test the feasibility and cost effectiveness of cross-

docking. An organization should simulate cross-docking to determine the true effects of cross-docking on cost structure. Organizations should quantify and qualify alternatives to determine the best combination of operating system components that will maximize system performance ("Cutting Costs with Crossdocking," 1995:3).

III. Methodology

Chapter Overview

The primary objective of this chapter is to propose a framework for constructing a decision support tool. It is proposed such a tool could be used to evaluate the time and cost performance of current military distribution center (DC) operations. Then the tool could be used to evaluate the cost and time performance of the same DC, modified to incorporate commercially successful cross-docking distribution methods. The measurements from these could be compared and the results could be used to help DoD logistics planners make DC efficiency, effectiveness, investment, reengineering, customer service, etc., decisions. This decision support tool consists of a contemporary computer simulation modeling and a proposed Activity-Based Costing (ABC) model to measure the time and cost performance of the DC and its modified cross-docking version. To demonstrate the framework for building this decision support tool, computer simulation and Activity-Based Costing (ABC) models were constructed for a hypothetical distribution center (Current Model) and a modified cross-docking version of the hypothetical DC (Altered Model).

As outlined in Chapter One, the specific objectives of this research are to answer the following questions: 1) What information is necessary to build a computer simulation model as a management decision support tool?; 2) What types of information is needed for an ABC model to cost DC activities?; 3) Can an ABC model of military logistics

activities and processes be meshed with a computer simulation model to provide DoD DC managers cost and time performance information to support DC design, quality, process improvement, reengineering, etc., decisions specifically regarding the use of commercially successful cross-docking distribution methodologies?; 4) What information will the decision tool provide managers? In an attempt to satisfactorily answer these research questions, the authors developed the methodology provided in the rest of this chapter.

Section One

Introduction to Computer Simulation Model Development

The general steps involved the using a computer simulation model for the study of real world systems include specification of objectives and available knowledge, model design, simulation runs, and model verification/validation (Zeigler and others, 1978:xii). These steps were used as part of the tool-building framework.

Collecting Information

The first step in creating the computer simulation modeling was to identify the objectives of the modeling experiment. The intended application of the research would be to use the simulation program as part of a decision support tool to compare time and cost performance of an actual DC and the same DC altered to incorporate advanced cross-docking methods. For the purposes of this presentation, the purpose of the simulation model was to provide such a comparison with a hypothetical DC. With that in mind, the next task in model design was to gather information necessary to build the model.

Information about typical military DC operations was primarily collected by on-site visits to the Consolidation and Containerization Point (CCP) of the Defense Distribution Depot in Susquehanna, Pennsylvania (DDSP)—part of Defense Distribution Region East, Defense Logistics Agency, Department of Defense. Also, interviews of

CCP workers, supervisors, and managers were conducted in person, by telephone, and via electronic mail. This site was suggested to the authors by members of the Headquarters United States Air Force Transportation Staff because it has the most advanced DC operations in the DoD, because it incorporates so many kinds of distribution processes and activities utilized in DoD DCs (Saccomano, 1995:43), and because the people who manage the operation were willing to aid the authors in this research.

In addition to visiting the CCP, the authors toured The Limited, Airborne Express, and Emery Worldwide central hub distribution facilities in Ohio. This provided opportunities to compare some of the most advanced commercial DC and cross-docking methodologies with the DoD's best practices at DDSP.

The authors also performed an extensive literature review on the latest DC, warehousing, and cross-docking methodologies employed in both the public and private sectors. Interested readers are invited to contact the authors for a copy of an integrated annotated bibliography written on cross-docking in the literature.

General Description of a Military DC

The distribution centers of the United States military are part of the largest logistics pipeline in the history of the world (DDRE, 1996:5). The activities that occur inside their walls include receiving, storage, issuing, consolidation and containerization, packaging, packing, marking, physical inventory, quality control, and preservation of literally hundreds of thousands of different stock keeping units on a daily basis (Taylor,

1996/1997). The military logistics environment is relatively stable in peacetime, but when contingencies occur DoD DCs must be able to ramp up quickly, reliably, and accurately handle tremendous material flow volumes. The cost of slow or misguided material distribution may be measured in human lives under such conditions (Peters, 1996:46). These facts make the DC operation as complex and challenging as any commercial distribution operation.

Types of Materials Flowing Through a DC

In general, there are three primary sizes of items that flow through a military DC, directly impacting the methods by which they are handled. They are bulk items, items that fit on a pallet but are too big for a conveyor (pallets and pallet items), and bin-sized items that are small enough to be conveyable. The DoD handles hundreds of thousands of different types of items, owing to its size and diverse operations. However, the flow of materials through a military DC is generally dictated by the size categories.

Material Handling

The movement of items from one DC process to another, or from one activity to another within a process, may be performed by hand or motor lifts, manually pushed wheeled carts, automated tow line carts, or a conveyor system, depending upon the type or size of the item to be handled and the process at hand. The automated tow line carts in the CCP moved the bulk of pallets and palleted items and were directed to appropriate

DC locations based on information about the pallet item scanned into a warehouse management system at pallet receipt. Their routing throughout the DC was then controlled by the warehouse management system. The CCP had 1,150 tow line carts and were never a capacity-limiting factor except during contingencies such as Operation DESERT STORM. The same was true for the conveyor system, consisting of 970 tote spaces. In the CCP the conveyor system was called a "gull-wing" and was used for most movements of bin items. The term "gull-wing" describes the shape of the conveyor racks that hold each item as it is conveyed throughout the CCP (Taylor, 1996/1997).

Description of Distribution Center Processes

The basic distribution processes observed in the DC at Susquehanna were receiving, storage, packing, and shipping.

Receiving Process Description

Receiving generally consisted of activities such as signing a Bill of Lading (BOL) for items, unloading the items with a forklift and placing them in a break bulk area, sorting by full pallets that are bound for a single destination or breaking out "tri-wall" or "multi-wall" containers (large, thick-walled cardboard boxes) full of items bound for multiple destinations, moving items to in-check, and "receipting" items at in-check stations. The majority of items bound for DoD DCs are hauled by truck (Taylor, 1996/1997). Receiving areas had many crews to meet the trucks, consisting of a

supervisor who signed the BOL, forklift drivers to unload the trucks, break-bulk workers to separate out the items, and in-check workers who worked at computer stations electronically receipting items.

Storage Process Description

Storage in the DC was divided between the smaller bin items that fit into small bins and larger pallets holding many of one item or a few large items. The storage process for both binnable and pallet items consisted of activities including movement to and from in-check in the receiving process, put-away of items into storage locations, and retrieval or "picking" of items from storage locations.

Packing Process Description

The term packing in the presentation is used to describe containerization of binnable items into tri-walls and pallet processing. In the CCP, containerization consisted of consolidating small items bound for similar destinations into large tri-wall boxes. Pallet processing generally consisted of wrapping, weighing, and marking palletized materials in preparation for shipping.

Shipping Process Description

In the CCP pallets were taken from the tow line carts coming out of pallet processing and forklifted to consolidation areas on the shipping dock. When enough pallets accumulated until there was enough to fill an outbound truck or sea van container, the shipping supervisor filled out shipment. Once that was done, forklift drivers loaded the pallets into waiting trucks or sea van containers. As in the receiving area, many crews performed these shipping activities.

Hypothetical Current DC Flow Chart

Using the information gathered by site visits, and according to the descriptions of processes and activities above, a flow chart of a hypothetical current military DC was constructed. The chart was built as a simplified version of the CCP operations. It included all major processes and activities along the main flow of items into, through, and out of the Susquehanna DC, but in a much simplified form. For example, processes concerning hazardous materials, frustrated cargo, and high security items were not modeled. This may be considered one of many limitations to the general model constructed, but it is intended that the framework provided be applied to these processes, and their related activities, in the construction of an actual decision support tool. For ease of reference hereafter, the hypothetical current DC computer simulation model will be called the Current Model, and the modified cross-docking version, to be explained later, will be called the Altered Model.

Current Model Receiving Process Flow

Items arrived to the receiving section of the Current Model by trucks. There a receiving crew received incoming items. A supervisor checked the load and signed the Bill of Lading. Then a forklift driver unloaded the truck and placed pallets in the break-bulk area. Breakdown workers separated the pallets. They opened the tri-wall boxes containing items with various destinations, placing conveyable bin items in a canvas tote cart and non-conveyable "pallet items" individually on tow line carts. They used hand lifts to place single-destination pallets on tow line carts.

Pallets that did not need broken down went through a pallet receipt activity. From there, the pallets continued on the same tow line cart to one of three places. Items bound for storage went to the pallet store activity. Non-conveyable bin items were carted to the tri-wall build-up activity in the packing process. Full pallet items bound for shipping were carted to the pallet processing activity in the packing process.

Whenever the canvas tote cart of bin items (sitting in the break-down area) filled up, a break-down worker pushed it to the bin receipt area where they were scanned through an in-check as with the palleted items. Once scanned, the bin items were placed on a gull-wing conveyor bound for storage or the tri-wall build-up activity in the packing process.

Storage Process Flow

Items flowing into military DCs may be bound either for storage or outbound for operational units. Bin items needing storage were taken off the gull-wing conveyor, after their journey from bin receipt, by a bin storage worker and placed in storage. Bin items were picked from storage and placed by a bin-pick worker onto a gull-wing conveyor bound for bin receipt, and then for tri-wall buildup.

Pallet items needing storage arrived from pallet in-check by tow line cart. A pallet storage worker used a mechanical lift to move pallets from the tow line cart to the pallet storage location. A pallet pick worker reversed this process when pallets came out of storage for outbound shipment.

Packing Process Flow

Conveyable bin items arrived in the tri-wall build-up area from bin receipt via gull-wing conveyor. Non-conveyable items arrived from pallet receipt by tow line cart. A build-up worker placed items with common destinations in tri-walls for shipping, then used a hand lift to place full tri-walls on tow line carts bound for pallet processing.

At pallet processing, built-up tri-walls and unitized pallets arrived from pallet build-up and pallet receipt, respectively. A pallet process worker wrapped, weighed, measured, and labeled the pallets and released them on their way to be consolidated in the shipping area.

Shipping Process Flow

Processed pallets arrived to the shipping area by tow line cart. There a forklift driver consolidated them into loads by destination. When enough pallets accumulated to fill a truckload, the shipping supervisor filled out the shipping paperwork, and a forklift driver loaded the pallets onto a truck.

Completed Current Model Flow Chart

The flow of items through the Current Model is shown below in Figure 7. This flow chart provided the basis for construction of the computer simulation model for the hypothetical current distribution center.

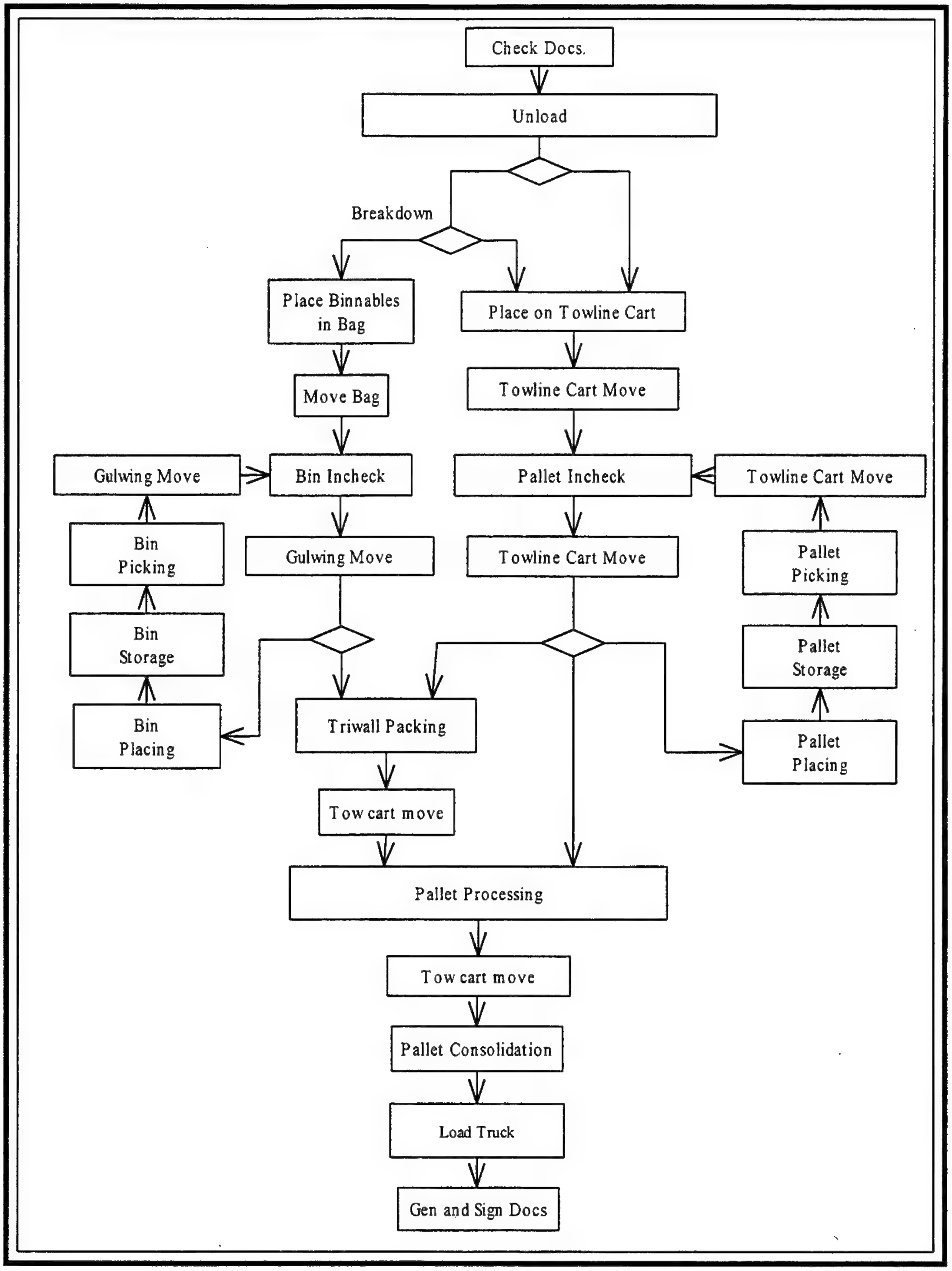

Figure 7: Flowchart of Current DC

Computer Simulation Modeling of Hypothetical Current DC

The numbers used to construct the simulation model do not represent, or even attempt to model, an existing military DC. Rather, the DC at Susquehanna was explored to get a general idea for the kinds and types of activities that occur in, and materials that flow through, a typical military DC. The emphasis of this research, as stated earlier, is to provide a framework for managers to construct a simulation model of their own DC as a decision support tool. These qualifications apply as much to the characteristics of the materials flowing into, through, and out of the generic DC model as to any other part of this study. The authors decided modeling pallet items and bin items (representing the majority of material flow through the CCP) would suffice to provide examples needed for developing the tool-building framework. It is intended that methods used in the framework provided by this thesis may be applied to activities involving the processing of bulk, hazardous, frustrated, etc., cargo.

Simulation Modeling of DC Resources

Resources modeled included workers, tow line carts, gull-wing conveyor totes, and bin and pallet storage locations. In general, only one work crew was modeled for each distribution process. For example, one crew, consisting of a supervisor, a forklift driver, two break-bulk workers, a bin-receipt worker and a pallet receipt worker, was used for the receiving process described earlier. The forklift drivers were assumed to always

have a forklift available for their use. This was typically true in the CCP, but could be modeled as a constraint if it exists in a real system.

Similarly, less tow line carts and gull-wing conveyor totes were used in the model. Interviews of the CCP revealed these resources have only been capacitated during contingencies such as Operation DESERT STORM (Taylor, 1996/1997). The numbers used in the model were adequate to prevent capacitation or any significant queue build-ups. The selection of material handling methods and equipment was based on those used in the CCP. However the modeling methodology is intended to apply to any form of material handling.

The bin and pallet storage location capacities are also far smaller in the model than in the CCP, but were not capacitated in the model runs. Resources such as conveyor systems and storage capacity could also be constraints in some operating military DCs, and should be modeled as such where appropriate.

Simulation Modeling of DC Items

To match the scaled back number of resources, fewer trucks (and so fewer items) were introduced into the model for processing. The important concept is that the number of items put into the Current Model did not change for the altered model, so that the methodology for showing differences in efficiency, cost, etc., could be shown.

Break-bulk workers sorted multiple-destination tri-walls from unitized pallets in the receiving process. To roughly estimate CCP percentages, 80 percent of inbound

pallets were modeled as unitized pallets and the remaining 20 percent as tri-walls needing break-bulk action. This split determined the proportion of work load throughout much of the CCP and in the simulation models. It will be demonstrated later how changing this to a 90/10 split could significantly decrease the percentage of available capacity used within the DC. Additionally, a percentage of the items coming out of tri-walls are too large to convey and become "pallet-items." A 95/5 split was chosen, based on observation of CCP operations and information provided by DC workers and supervisors, defining 95 percent of the binnable items as "conveyable" and five percent of the items as "non-conveyable." This was not changed in the altered model. It was included to show how to model variations to the normal distinction between tri-wall items and unitized pallets.

As mentioned earlier, items received by the DC are bound for either storage or shipping. For the Current Model, a 60/40 split was chosen, with 60 percent of items received going into storage and the rest outbound. This split was modeled to provide a basis against which the Altered Model split (40/60 as described later) could be compared. The model tracked which items were original receipts and which came from storage to maintain model integrity. Without such tracking, items coming out of storage may wind up going right back into storage following the in-check activity.

One final characteristic of the items flowing through the model is there outbound shipping destination. The CCP shipped items to many destinations all over the world. To demonstrate this concept, model items were randomly assigned one of two possible operational unit destinations. This destination affects how the items are batched for shipment in the model.

Weight and dimensions were not assigned to individual items in the model. This exception was handled by simply assigning the above described percentages to the types of items flowing through the modeled DC. There may be instances where weight and dimension must be modeled. If these characteristics are desired or needed for modeling an actual facility, they can be assigned as "entity" attributes just as item destinations were. However, the authors believe the modeling design used correctly describes typical item flows in a distribution center, and the use of weights and dimensions may not be necessary. Additionally, tracking weights and dimensions of every item through a DC for the purposes of building the decision support tool may prove cost- or computer filespace-prohibitive, if not impossible.

Simulation Modeling of DC Activities

Perhaps the most crucial and difficult part of constructing any model is estimating accurate times involved in the performance of each real-world activity. This primarily consists of fitting a hypothetical statistical probability distribution (PDF) to historical empirical measurements of item arrival and processing times to and/or through each modeled activity. Such probability distributions, if estimated properly, can then be used in a computer simulation model to emulate real-world activities. Accurate estimation can take many days, weeks, months, or even years of measuring actual activity accomplishment (Guide, 1996). Unfortunately, this is not currently done in DoD DCs.

This then becomes a manager's first and greatest challenge when contemplating the construction of a decision support tool as outlined in the present research.

Finding the DoD does not have or track such data, the authors selected reasonable probability distributions based on observing activities in the CCP for several days, personal interviews with the employees and supervisors that work in the CCP at DDSP, and advice from simulation modeling experts (Guide, 1996; Johnson, 1996; Kraus, 1996; Banks and others, 1996).

Creating the Computer Simulation Model

The next step in the process to build a decision support tool was to write the computer simulation model of a DC as it presently exists. In this case, the hypothetical Current Model was used as the example. The authors used SLAM II simulation language, version 4.1, by Pritsker & Associates Inc. with guidance from Pritsker's text "Introduction to Simulation and SLAM II," 1986. In addition, SLAMSYSTEM Total Simulation Project Support, Student Version 4.8, was used for its graphical user interface (GUI) to create the network model statements. The GUI tool provided by Pritsker made simulation modeling of distribution center activities relatively simple. This admission is made in the interest of showing readers the tools of modern technology can by plied by virtually anyone to build helpful decision support tools.

The software SLAM II is a FORTRAN based simulation language, so some FORTRAN coding was necessary, as seen in Appendix A. The simulation experiments

were run on a Digital Equipment Corporation (DEC) VAX 6420 mainframe computer located at the Air Force Institute of Technology, Wright-Patterson AFB, Ohio, using a DEC VAX FORTRAN, version 6.1, compiler. The SLAM II program automatically interfaced between the compiler, the FORTRAN code and the SLAM II network statements, requiring only menu selection interface from programmers.

Using the simulation resources just described, the information gathered about typical military DC operations, and the developed flow chart, the computer simulation model program of the hypothetical Current Model was written.

Computer Model Verification

Most of the verification methods suggested by Law and Kelton (1991:302-306) were used as the model was developed. The model was built one DC process at a time and re-verified as each new process was added. Also, one of the authors designed the simulation program, while the other reviewed the model at different stages of development. The outputs were also checked for reasonableness by varying the number of entities input or the percentage of entity flows along different paths to ensure logical results occurred. Comparisons of the means and variances of the theoretical probability distribution functions (PDF), used to model individual activities, to the simulation outputs was also accomplished throughout model development as a quick check to see if the model achieved steady state. Finally, as mentioned earlier, the SLAM II simulation package was used for model construction, vastly simplifying the task of writing logical

computer code. Using these verification techniques, model bugs were quickly identified and eliminated at each stage of model development, including the final model.

In addition to the above verification procedures, a combination of procedures recommended by Pritsker (1986:751-752) were used to "start" the model in steady-state conditions, thereby reducing the variance inherent in the warm-up stage of random number generators.

Model Validation

There are many texts describing several methods for validation of computer simulations (Banks and others, 1996; Law and Kelton, 1991; Pritsker, 1986). According to Law and Kelton, the best possible way to validate a simulation model is to compare its outputs with the system under study (1991:311). This was not possible for the present study, since no actual system was modeled. However, several other methods suggested for model validation were applied.

One method used to attain model validity was using information gathered from system experts and direct system observations to design the model. Law and Kelton (1991:309) emphasize the importance of maintaining constant communication with system experts, managers, workers, etc., who know the system, while designing and building the model. Since the authors used the CCP at DDSP for guidance in developing a hypothetical DC operation, the communication suggested by Law and Kelton was accomplished via on-site visits of the CCP, telephone conversations, and many electronic

mail question and answer sessions about CCP processes and activities. Though the models designed in this study were theoretical, the authors believed it was important to use real-world nomenclature and the characteristics of actual DoD distribution center processes, activities, materials, resources, flows, etc., to put the subject of the present research in a familiar context for readers.

Another method used to ensure model validity was sensitivity analysis, as suggested by Law and Kelton (1991:310), to see if, and how much, the simulations outputs changed as a result of changing parameters, such as PDF parameters describing activity characteristics. One example of sensitivity analysis used was validating of the model by viewing the affects of altering the inventory storage/direct shipping split discussed earlier. For example, the initial generic model was designed with a 60/40 split, where 60 percent of the items coming into the DC went into storage and the remaining 40 percent flowed to shipping. This split was changed to 40/60 and similar percentage changes to storage resources' utilizations were observed, validating that the model behaved as expected. Similar sensitivity testing was conducted throughout the model for validation.

Current Model Results

When the Current Model was constructed, verified, and validated, 15 runs (or replications) were made and the mean times of all the simulated activities within each run were averaged across the runs. The summarized results from these calculations are

provided in Appendix A. The means across runs, total number of observations, and total time the activity was performed, as shown in the table, were used as inputs to the ABC model of the hypothetical Current DC.

In addition to the activity statistics obtained from the simulation run outputs for ABC model inputs, statistics on times items spent in queues waiting to be processed through the activities were recorded for inclusion in time performance analyses (Chapter Four). These await times for the Current Model are also summarized in Appendix A. The values were recorded for all 15 runs and the averages across the runs were taken, as with the activity times.

Computer Simulation Modeling of Altered DC

The methodology for changing the model to incorporate additional cross-docking methodologies is similar to the methodology demonstrated earlier in this chapter for the Current Model. The following alterations were made to the Current Model, using model integrity and verification checks along the way. The flow chart used to guide model alterations is shown in Figure 8, below. The changes are described in the following paragraphs.

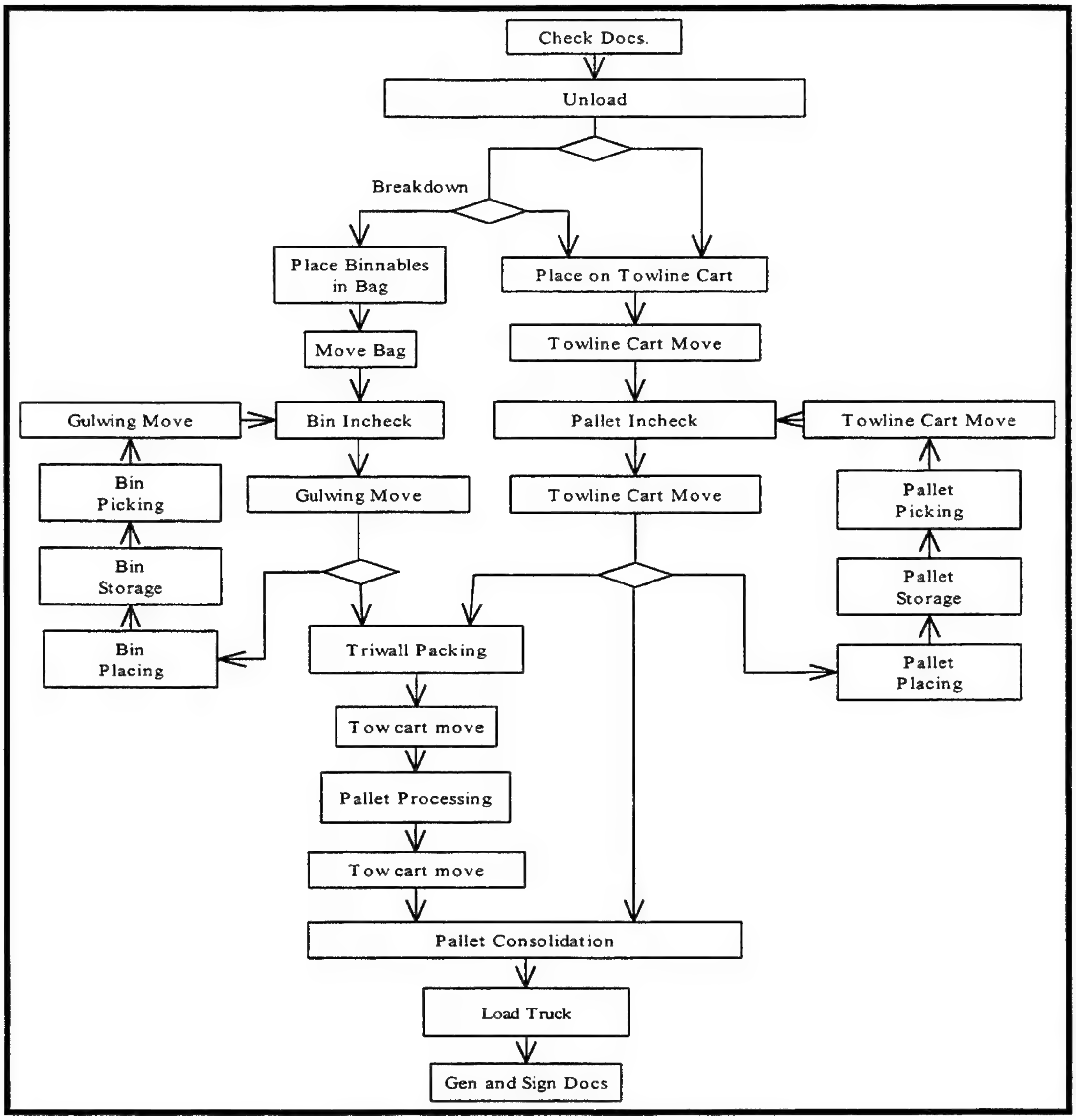

Figure 8: Flow Chart of Altered Model

More Cross-docking, Less Inventory

The Current Model sent 60 percent of incoming material into storage and the remaining 40 percent was cross-docked for consolidation and shipment. The first alteration made was to reverse that split. The Altered Model was designed to send 40 percent of incoming materials into storage and the remainder to shipping. This was done

to see what effect it may have on DC times and costs. For modeling purposes, the only alteration required was to change one array value in line 4 of the code from .6 to .4 (compare the computer coding in line 4 of both models in Appendix A). This first alteration demonstrated the ease and power of using computer simulation modeling for decision support—estimations of effects on real world processes, activities, costs, customer satisfaction, etc., could be made without stopping, changing, or otherwise having to bother the real system and with one simple stroke on a computer keyboard.

Increased Shipper Consolidation

The next alteration was to simulate an increase in the percentage of items pre-consolidated into unitized pallets from that of the Current Model. In the real world this would require supply chain partnerships, coordination, and agreements. The requirement for this in the Altered model was to decrease the number of tri-wall pallets that need break-bulk into individual binnables, and translates to reductions in bin-item related activities throughout the model. To make this change the only necessary action was to change the percentages in lines 288 and 289 of the Current Model code from .2 and .8 to .1 and .9 respectively. Again, this demonstrates the ease of using simulation to model real world system changes.

High-Technology In-Check

Another simulated improvement to the Current Model was the replacement of the in-check workers at bin receipt and pallet receipt with automatic scanners. This would require tremendous cooperation from shippers, as with the consolidation alteration just described. For this to work, shippers would have to pre-label all packages with scannable barcodes. It would also require DoD to purchase and install the necessary hardware and software. The decision support tool of the present research may possibly be used as a cost-benefit analysis tool for such an investment. The only change made in the Current Model program to implement this auto-scan change was to change the in-check activities times from a probability distribution function to zero. This assumes the automatic scanning process can be set up to occur as items go by on a gull-wing conveyor or towline cart. Such technology was seen by the authors on visits to commercial DCs and found throughout the literature on cross-docking.

Less Pallet Processing

The final alteration made to the Current Model is a logical extension of the second and third modifications. If nearly all pallets were unitized, and if shippers would put the necessary bar codes on them for automatic in-check, then it is likely the pallets would already have all pallet processing functions accomplished before they arrive to the DC. That is, with cooperation, and likely the incentive of shared benefits, pallets may be pre-labeled, pre-weighed, and pre-wrapped, obviating the pallet processing activity in the DC.

Since some items from inbound multi-destination tri-walls and storage issues would still require pallet build-up, the pallet processing could not be totally eliminated. However, the towline cart from the pallet receive function could bypass the pallet processing activity and go straight to consolidation. This was accomplished in the model by changing the go-to destination in the towline activity, coming out of pallet receiving, from pallet processing to consolidation. This required only two minor coding changes, since a GUI was used for modeling. This would have been slightly more complex were line by line coding used, however it is a relatively simple change compared to writing a new model code, and especially compared to the difficulty of evaluating the effects of such a change in a real system.

Altered Model Results

A simulation experiment of the altered model was run in the same manner as with the Current Model, using the common random number streams concept suggested by Law and Kelton (1991), to enable comparisons between the models. The summarized outputs for the Altered Model activity times are shown in Appendix A, and were used as inputs to the ABC model of the altered DC for costing analysis.

As with the Current Model, statistics on times items spent in queues waiting to be processed through the activities were recorded for inclusion in time performance analyses (Chapter Four). These await times for the Altered Model are also summarized in Appendix A.

Section Two

Introduction to Activity-Based Costing Model Development

From the literature review in Chapter Two, it was discovered implementing Activity-Based Costing (ABC) has greatly benefited commercial logistics organizations. Furthermore, groundbreaking research by Callahan and Marion showed implementing ABC into DoD service organizations was both feasible and beneficial: It provides a means to allocate organizational resources to a set of activities, allowing for the determination of specific activity costs. Traditional government accounting systems are unable to do this (Callahan and Marion, 1994). The review of literature, in Chapter Two, also determined ABC is used by managers for two purposes. One purpose is for the pricing of specific products or services and the other is for the costing and management of activities (Beaujon and Singhal, 1990:51). The first purpose does not apply to the present research regarding military DC processes and activities, therefore no attempt was made to generate specific product or service costs. However, the management of activities was the key ABC purpose examined in this research.

Activity-Based Costing facilitates the management of activities because it focuses managers' attention on improving activities that have the largest impact on costs, enabling managers to take measures to effectively reduce those costs and to use organizational resources more efficiently (Cooper and Kaplan, 1991:130). To do this, ABC models must first be designed to facilitate managers' understanding of how

activities consume the resources in an organization (Beaujon and Singhal, 1990:51). Second, ABC models must be able to discern between the costs of resources used versus resources unused by particular activities (Cooper and Kaplan, 1992:1).

In Section One of this chapter, a computer simulation model was developed to simulate the processes and activities model in a hypothetical DoD distribution center. In Section One of this chapter, this simulation model was referred to as the Current Model. One of the objectives of this research was to develop an ABC model to be combined with the simulation model. However, as found by the present authors in their literature review, the use of simulation for costing of activities and product cost allocation is an unexplored area in ABC literature (Raghu, Chaudhury, and Rao, 1997:3). Furthermore, ABC and simulation has not been used in combination to simulate and cost specific activities in a DoD distribution center (DC).

This section's purpose is to propose a methodology for designing and constructing an ABC model to be used in concert with a computer simulation model in an attempt to answer the following research questions:

1. What types of information are needed for an ABC model to cost DC activities?
2. Can an ABC model of military logistics activities and processes be meshed with a computer simulation model to provide DoD DC managers cost and time performance information to support DC design, quality, process improvement, cost reduction, reengineering, etc.?
3. What information will the decision tool provide managers?

In answering the above research questions, the objective of this research was to propose a framework for generating a management decision tool (ABC and simulation

models combined). Such a tool could provide logistics managers both cost and time performance measures of currently existing DC processes and activities. Then managers could alter a current computer simulation model with changes to processes in the DC, such as the implementation of modern cross-docking technique, to demonstrate how possible changes in both time and cost performance could be shown.

Overview

This section will provide a framework for developing an ABC model for costing DoD DC activities while using data provided from a computer simulation model of the same DC. The framework explains the four steps in ABC model development, how to use simulation data to generate the costs of activities used within the developed ABC model, and how to generate an activity usage statement.

Steps in ABC Model Development

The authors of this research developed a hypothetical ABC model of a current DoD distribution center using a methodology derived by Callahan, Marion, and Pohlen. Their methodology outlines four major steps in ABC model development. The four steps are: 1) get top management input; 2) create an organizational chart of activities; 3) trace organizational resources to activities; and 4) trace activities to organizational products or services (Callahan, Marion, and Pohlen, 1994:38-42). Several key activities have been

highlighted to provide a detailed understanding and to demonstrate how the model was developed using the four steps above.

Step 1. Top Management Input on Use of an ABC System

Since managers are the primary users of ABC information, they should be consulted on what types of information they want the ABC model to provide. For example, the key issues to discuss with management before implementation of an ABC model into a DoD distribution center would include: 1) what is the purpose of the model; 2) what level of detail is required; 3) what organizational costs will the ABC model consider; and 4) how will the model be constructed and maintained (Callahan, Marion, and Pohlen, 1994:38)?

In the hypothetical context of this study, management input for this study's particular ABC model was not actually used. However, this hypothetical ABC model was developed to enhance the management of DoD distribution center (DC) activities.

Purpose of the ABC Model

The purpose of this ABC model was to use performance output data from a computer simulation model of a hypothetical DoD DC (Current Model) to generate ABC information about specific DC activity costs. The Current Model simulation provided data of DC processes over a two month time period, thus, the ABC model developed costs over a two-month period. Changes were then applied to the Current Model,

mimicking the implementation of modern cross-docking techniques within the hypothetical DC. This changed model was referred to as the Altered Model in Section One of this chapter. These changes were then simulated and the simulation outputs again were put into the ABC model to generate activity cost information. Activity-Based Costing results from the Altered Model were analyzed and compared to ABC results of the Current Model to understand how changes upon certain DC activities affect activity usage and associated costs. Thus, the purpose of this model was to assist the managers in their abilities to manage their activities and to help managers understand how overall DC costs are affected by implementing new DC techniques, such as cross-docking .

This objective was accomplished by addressing two management implications. First, the ABC model was developed and designed to increase management's understanding of how activities affect costs in the distribution center as described by Beaujon and Singhal (Beaujon and Singhal, 1990). Second, the ABC model was developed and designed to discern the costs of resources used versus resources unused by the activities in the model as described by Cooper and Kaplan (Cooper and Kaplan, 1992:1).

Level of Detail

Beaujon and Singhal describe that consideration of the level of detail in an ABC model is very important in ABC model design. An appropriate level of detail is needed in concert with designing a model to ease managers' ability to correctly associate costs with activities and to enhance managers' ability to easily interpret ABC information. To

do this, ABC models should first be designed and developed so that activity costs are available in the form of resources, activity centers (activities), first-stage cost drivers, and second-stage cost drivers (Beaujon and Singhal, 1990:51,70).

Costs Considered

This hypothetical ABC model considered all the costs associated with the activities in the distribution center that are directly conducted on the handling, movement, and storage of distributed materials.

Construction and Maintenance

The model was constructed and maintained on a common spreadsheet program. Callahan and Marion, in their research, developed an ABC model using Microsoft's Excel spreadsheet software package. They mention that Excel was used because: 1) the software was already available, 2) a large learning curve was not necessary to use the software, and 3) the Excel software had the capabilities necessary to develop an ABC model (Callahan and Marion, 1994:74). The Microsoft Excel software package was used to develop the ABC model in this research effort as well.

Step 2. Create an Organizational Chart of Activities

To develop a chart of activities, the ABC model builder must first understand what organizational costs the ABC model will consider. As was determined, all activities

that deal with the direct handling, movement, and storage of distributed materials are considered.

Information Needed (Step 2)

A thorough understanding of the distribution center processes and activities to be considered is imperative. Development of a detailed flow of materials through the distribution center is suggested to gain the knowledge required to construct a comprehensive chart of activities (Pirtilla and Hautaniemi, 1995:327). When developing the chart of activities, it is best to identify and analyze the pertinent, key processes first. This is done because it is simpler to start at a macro level with processes and then work down to specific activities while gathering greater levels of detail in the process (Callahan, Marion, and Pohlen, 1994:40).

Model Development (Step 2)

The authors in this research conducted several site visits, including a DoD distribution center. These visits led to the authors' detailed understanding of what processes and activities were used to facilitate material flows through a distribution center. A materials flow diagram was constructed, based on the flow chart shown in Figure 7, and the activities within the diagram were labeled, as shown in Figure 9, and as described below.

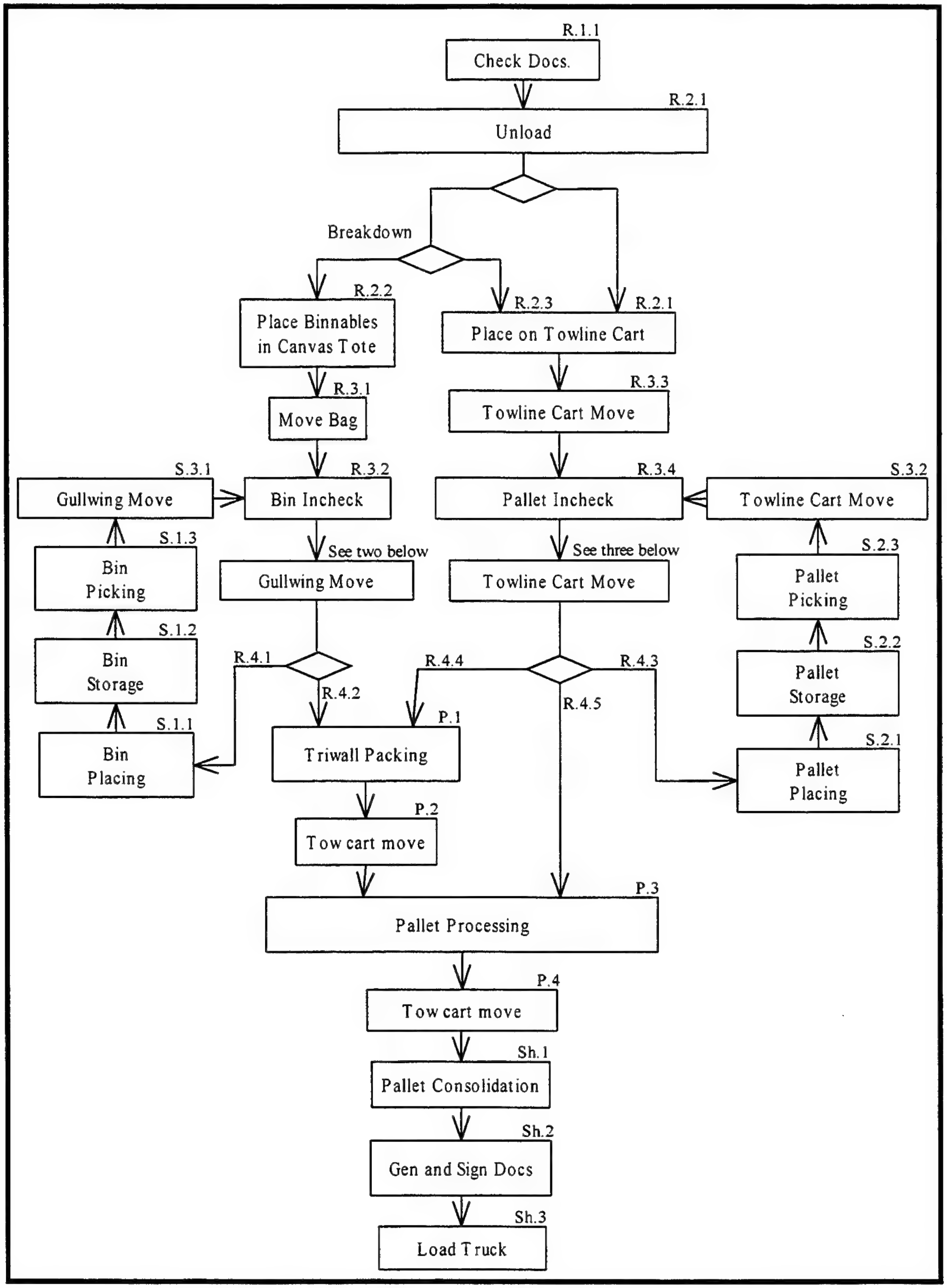

Figure 9: Labeling Activities in Material Flow Diagram

Within the flow diagram four key processes were identified. The four key processes were: 1) Receiving ; 2) Storage; 3) Packing; and 4) Shipping. After these four key processes were identified, individual activities were identified within each process. Next a list of activities within each process was constructed. The list of activities for the critical processes can be seen in Figure 10 below. The cost of each activity listed in the chart of activities was considered in the ABC model. The materials flow diagram contains and lists each of the activities that were costed in the ABC model, and provided a general understanding for how materials flow to and from each activity in the distribution center. Several key activities were analyzed in detail and used for comparisons to illustrate the proposed ABC model building frame work:

1. Pallet In-check (Activity R.3.4). This activity involved the use of one worker at one manually operated computer in-check station. As pallets came from the receiving docks, pallets were entered into the computer. Once entered into the computer system, the pallet was directed to either pallet storage, packing, or to pallet processing for shipment preparation.

2. Pallet Storage (Activity S.2.2). This activity simply involved the storage of pallets in pallet locations until they were ready to be picked, packed, processed for shipment.

3. Pallet Processing (Activity P.3). Pallets arrived in Pallet Processing from either the Pallet In-check station (Activity R.3.4) or from the packing area of the facility. In this activity, the prepared pallet was first weighed and dimensioned. Then the pallet was processed into the computer system for labeling and to store data records that the pallet was being shipped. After processing, the computer generated a label for shipment. The pallet was shrink-wrapped and the label was applied. Once complete the pallet went to the shipment area of the facility.

Receiving Process

Sub-process 1: Unloading	
Activity: R.1.1	- Check shipment documentation
Activity: R.1.2	- Unload shipment trailer

Sub-process 2: Pallet Sortation and Pallet Breakdown	
-Choose and sort "non-break" pallets from "breakdown" pallets	
Activity: R.2.1	- Place "non-break" pallets onto towline carts
Activity: R.2.2	- Remove "binnable" items from "breakdown" pallets and place into consolidation bag
Activity: R.2.3	- Remove "palleted" items from "breakdown" pallet then strap item onto towline cart (TLC)

Sub-process 3: Movement And Incheck	
Activity: R.3.1	- Move "binnables" consolidation bag to bin incheck station
Activity: R.3.2	- Incheck "binnables" into computer system
Activity: R.3.3	- Move "palleted" items and "non-break" pallets to pallet incheck station via TLC
Activity: R.3.4	- Incheck "palleted items" and "non-break" pallets into computer system

Sub-process 4: Movement out of Receiving Area	
Activity: R.4.1	- Move "binnable" items to bin storage via gullwing system (GW)
Activity: R.4.2	- Move "binnable" items to packing process via gullwing system
Activity: R.4.3	- Move "palleted" items to pallet storae via towline cart system (TLC)
Activity: R.4.4	- Move "palleted" items to packing via TLC
Activity: R.4.5	- Move "non-break" pallets to pallet processing via towline cart system

Storage Process

Sub-process 1: Bin Storage, Placing, and Picking	
Activity: S.1.1	- Place "binnables" into bin storage
Activity: S.1.2	- Bin storage activity
Activity: S.1.3	- Pick "binnable" item from bin storage

Sub-process 2: Pallet Storage, Placing, and Picking	
Activity: S.2.1	- Place "palleted" items into pallet storage
Activity: S.2.2	- Pallet storage activity
Activity: S.2.3	- Pick "pallated" item from pallet storage

Sub-process 3: Movement from Storage	
Activity: S.3.1	- Move "bin-ables" item to incheck via gullwing
Activity: S.3.2	- Move "palleted" item to pallet incheck via TLC

Packing Process

Activity: P.1	- Pack triwall cartons with "bin-ables" and "palleted" items
Activity: P.2	- Move packed triwalls, on pallets, to pallet processing via towline cart system (TLC)
Activity: P.3	- Pallet processing – Weigh pallet – Dimension pallet – Shrink wrap pallet – Label pallet – Process finished pallet into computer
Activity: P.4	- Move processed pallets to shipping via TLC

Shipping Process

Activity: Sh.1	- Remove processed pallets from towline cart and place in consolidation area
Activity: Sh.2	- Process load and generate shipping documents
Activity: Sh.3	- Load pallets into outbound truck

Figure 10: Current ABC Model Key Processes and Activity Labels

Step 3. Trace Organizational Resources to Activities

Beaujon and Singhal demonstrated ABC's two stage cost assignment process that was originated by Cooper. In the first stage, direct and indirect resources are split up and traced to individual portions (i.e., the activities) of the distribution center's overall process with the use of first-stage cost drivers. These first-stage cost drivers also provide the cause-and-effect relationship between organizational resources and activities (Beaujon and Singhal, 1990:52; Harr, 1991:24).

The consumption of resources in a DoD organization are tracked by element of expense investment codes (EEICs, i.e., cost codes). These cost codes trace resources vertically to organizational departments rather than individual activities (Harr, 1991:23; Callahan, Marion, and Pohlen, 1994:40). This method of tracking resource expenditure does not provide managers with a detailed knowledge of activity costs because organizational activities often cut horizontally across departments. An ABC model is needed to split up the resources aggregated in cost codes to individual activities so as to accurately determine activity costs (Callahan, Marion, and Pohlen, 1994:40).

Information Needed (Step 3)

In order to complete Step 3 (the tracing of resources to activities), the resources must be identified and the first-stage cost drivers must be identified. Callahan and Marion stated, in their research, that managerial input is important in identifying and choosing both resources and cost drivers. They suggest interviewing several experts within the organization to identify which resources are consumed by the activities

considered in the model and to identify the most likely first-stage cost drivers (Callahan and Marion, 1994:65-66).

Model Development (Step 3)

For the present research, ideas for resources consumed by activities included in the hypothetical ABC model were drawn from the experiences of on site visits to DLA's DC in Susquehanna, Pennsylvania. For example, ideas for resource cost data were found in DLA cost codes voluntarily provided by accountants of the Defense Distribution Region East staff (Kulp, 1996). However, actual resource cost figures from DLA cost codes were not used in this ABC model. This was done for two reasons. First, the simulation model of the distribution center did not simulate the exact operations of the DLA DC visited. Due to the extremely complex nature of the site's operations and due to limited amount of time that the authors could dedicate to modeling such complex operations, a more simplistic simulation model was developed. Thus, since exact operations were not modeled, exact costs were not used. That would have been unrealistic. Second, the cost codes collected resource cost figures at too high of an organizational level. For example, the DLA cost codes were collected and maintained for the Defense Distribution Depot in Susquehanna, Pennsylvania (DDSP). Under DDSP, both the Mechanicsburg and the New Cumberland distribution centers are organized. DDSP cost codes are collected and aggregated for both distribution centers into single cost codes. As a result, resource cost figures were not available for the site studied by the authors, the New Cumberland DC. Again, due to complex nature of the cost codes and

due to the simplistic nature of the simulation model, exact resource costs were not used in this research. Instead, the authors used ideas from literature research and on-site visits to develop the generic resources and associated cost figures used in the ABC model. These generic resources and associated costs were developed with two ideas in mind. First, the resource categories and costs were developed in efforts to closely match the level of the developed simulation model and were based on a two-month period. Second, simplified resource categories and costs were developed and used to simply meet this research's objective of proposing a framework for construction of an ABC model and to demonstrate a methodology for combining simulation and ABC into a managerial decision tool.

All of the activities considered in the ABC model were identified above in Step 2 and listed in Figure 10. Since all the activities in the model were already identified, knowledge gained from on-site visits and literature was used to identify the resources consumed by those activities. Then these resources and associated costs were included in the model and listed in Table 1 below. Note that each resource is categorized by class (e.g., facility level, process level, and unit/batch level) and each is based on a two-month period.

Table 1: Resources, Costs, and Cost Drivers

Resources	Costs- (2 Months)	Cost Drivers
Facility Level		
Management	$23,200.00	% of Time Allocated
Admin. Support	$29,600.00	# Employees (%age)
Facility Costs	$130,000.00	% of Facility Space
Utilities	$60,000.00	% usage
Process Level		
Data Systems/Computer Supt.	$37,500.00	% Allocated
Equipment Maintenance	$67,000.00	# Work-orders (%age)
Unit/Batch Level		
Workers	$62,400.00	# Assigned
Supervisors	$32,000.00	# Assigned
Incheck Computer Stations	$8,000.00	# Assigned
Forklifts	$14,300.00	# Assigned
Pallet Jacks	$2,800.00	# Assigned

Again, overhead costs for the resources were arbitrarily assigned since the computer simulation model is hypothetical. While this makes the actual calculation results unreal, it does not make them necessarily unrealistic and should not detract from the objective of proposing a framework for construction of an ABC model. Rather, the authors argue potential users of the proposed framework should have access to cost analysts within their organizations to obtain accurate cost information.

The authors site visit confirmed that DLA cost codes record and contain cost figures for all resources on a periodic basis (monthly), except for equipment (forklifts, etc.). This is beneficial to this study because ABC models would normally consider annual costs; however, due to minor limitations in the simulation model, only a two-month period simulation was performed on the hypothetical distribution center. Thus,

using resource costs over a two-month period for this hypothetical ABC model is not entirely unreasonable.

The authors developed facility level resources which included, management, administrative support, facility costs, and utilities. All facility level cost contained labor and non-labor costs that were accumulated over a two-month period, except for utilities which did not contain labor costs. Management resources include the managers responsible for the entire distribution center. Administrative support resources include personnel acquired to perform administrative duties, such as payroll. Facility and utility resources are self explanatory.

The authors developed process level resources which included data systems/computer support, and equipment maintenance. Data systems/computer support resources are used to support various activities, such as maintaining data records of all items kept in storage, generating shipment documentation from computer data, and receipt and storing of items into the computer system to recognize that certain items have been received into the distribution center. Equipment maintenance resources conducted maintenance on forklifts, other equipment, and conducted maintenance on various areas within the facility. These resource costs were also hypothetical and determined for a two-month period.

Finally, unit/batch level resources were developed and included direct labor, supervision, and equipment. The direct labor resources are workers that work a 40 hour work-week for $15 per hour. Over the two-month period (8 weeks) in the model, workers are available for a total of 320 hours (40 hours per week times 8 weeks). Their two-

month salaries are $4,800 for each worker. The total number of workers provided in the Current Model was 13 for a total worker resource cost of $62,400. Similarly, supervisors, responsible for their respective processes (e.g., Receiving, Storage, Packing, and Shipping), work the same number of hours (320), but with an average hourly salary of $25. Supervisor's two-month salaries are calculated at $8,000 each. Four supervisors are included in the model with a total supervisor resource cost of $32,000. Equipment costs are also determined for a two-month period in which they were used. The equipment considered in this hypothetical ABC model includes forklifts, pallet jacks and computer in-check stations. In their research on ABC, Pirtilla and Hautaniemi calculated yearly capital costs for equipment used to perform various activities. The yearly capital costs were first calculated from each piece of equipment's replacement value. Second, using the replacement value, annuities were calculated over each piece of equipment's lifetime. These annuities were used as the resource costs in their ABC model (Pirtilla and Hautaniemi, 1995:329). Within the ABC model developed for this research project, capital costs for the forklifts, pallet jacks, and computer in-check stations were determined in the same way; however, the annual capital costs were divided by 12 months to get a monthly capital cost figures. Then capital costs for each piece of equipment was determined for a two month period. These resource cost figures can also be seen in Table 1. For example, there were two computer in-check stations with two-month capital costs calculated at $4,000 each, four forklifts with two-month capital costs of $3,575 each, and two pallet jacks with two-month capital costs at $1,400 each.

Once the resource cost figures were determined, first-stage cost drivers were selected. Distribution center management should be sought to discuss the selection of cost drivers for management should have a good idea on which cost drivers are appropriate.

The reader should note tracing of resource costs to activities was not performed within Excel in one complete step. To simplify the task of tracing resource costs to activities, the authors used two steps. First, all resources were traced to each distribution center process (e.g., Receiving, Storage, Packing, and Shipment) where the individual activities occurred. This first step aggregated all resource costs within each particular process. Figure 12 provides an illustration of the details of step one. In the second step, these aggregated costs in the process were then traced to individual activity cost pools. Refer to Figure 13 for an illustration of the details of step two.

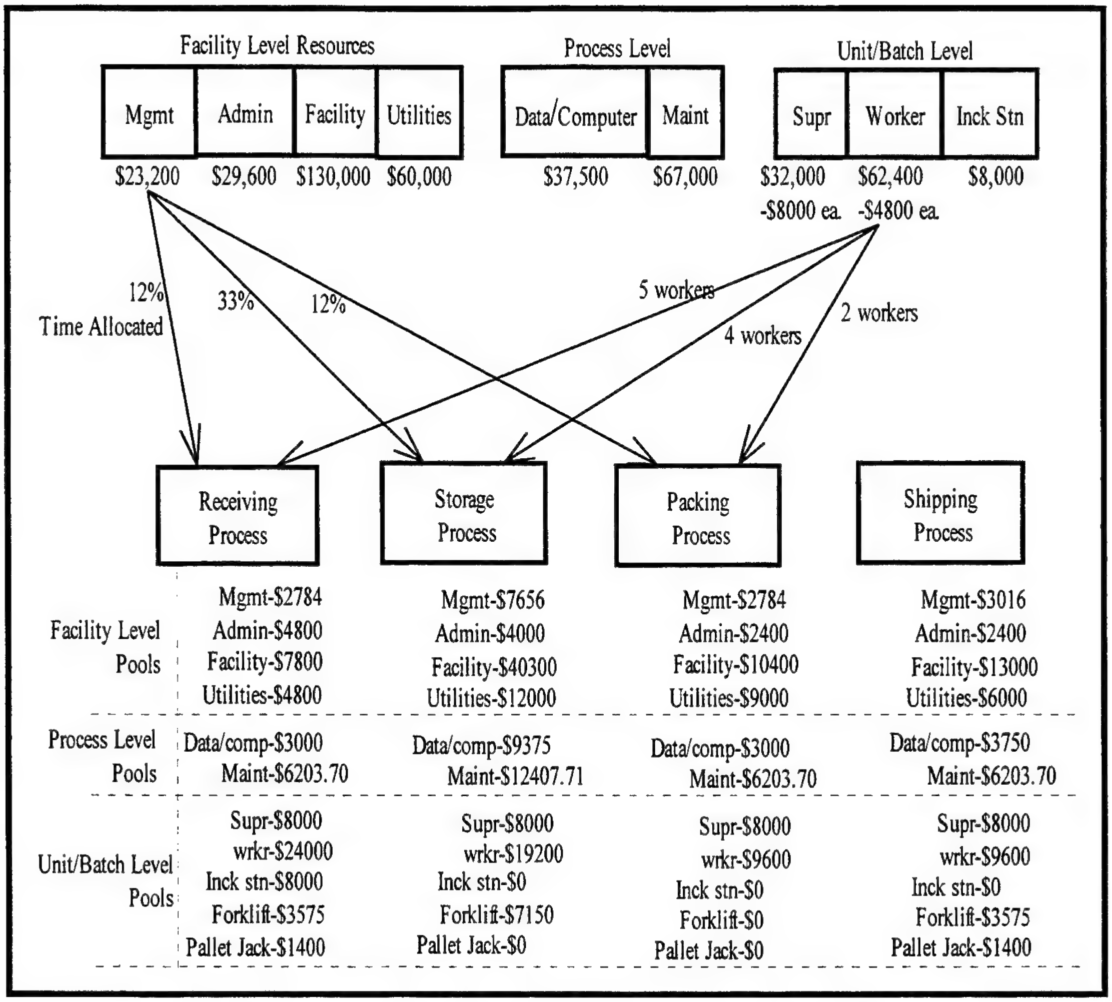

Figure 11: Aggregating Resource Costs into Specific Processes

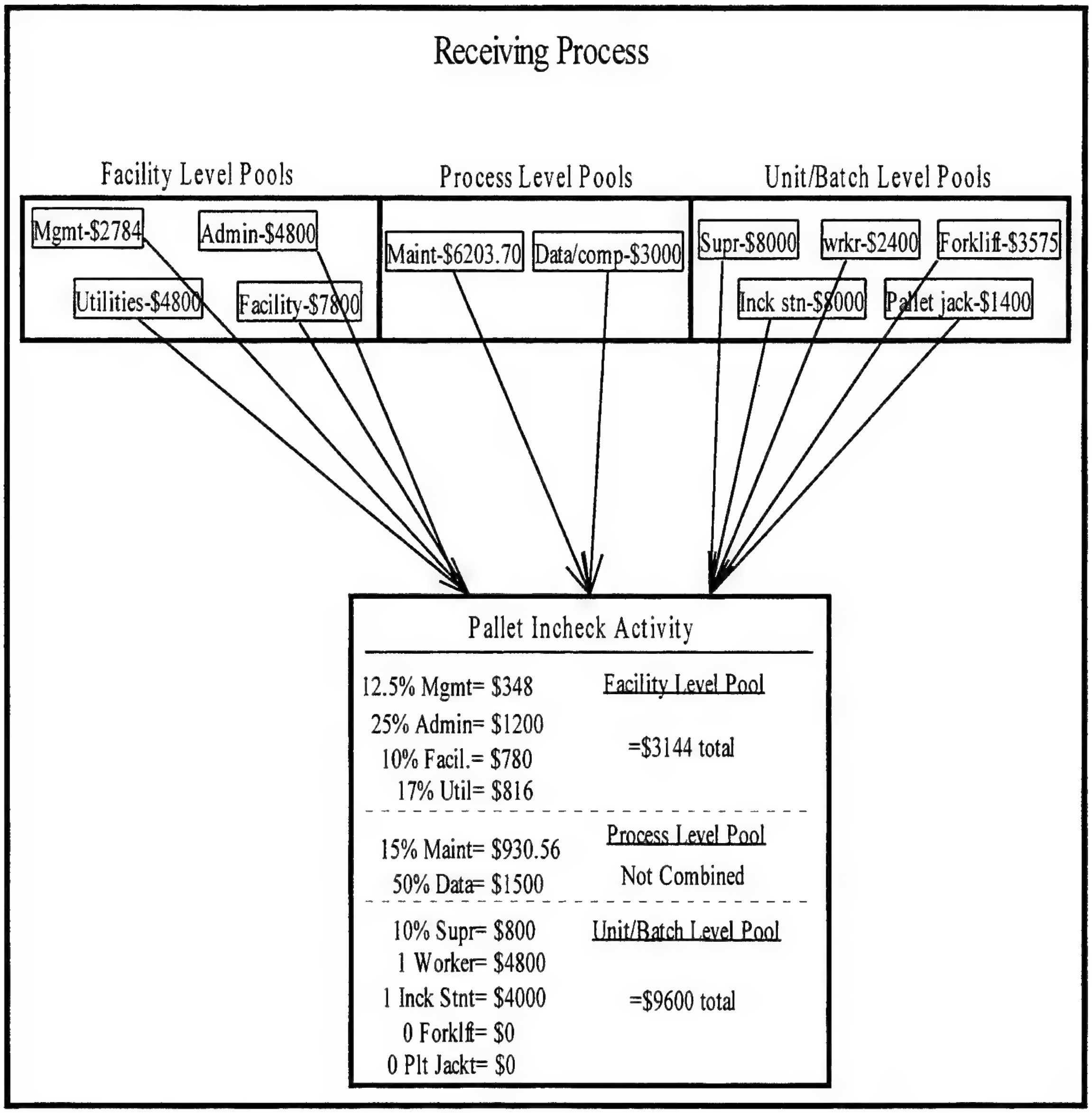

Figure 12: Tracing Aggregated Costs into Individual Activity Cost Pools

Management resource costs are split up and traced to individual activities' cost pools with a cost driver that was suggested by Callahan and Marion. Callahan and Marion used a cost driver that split up the management resource to activities by actual percentage of time that management dedicated to that particular activity (Callahan and Marion, 1994:273). This ABC model split and traced the management resource to the

major distribution processes by percentage of time dedicated to the process in the first step. In the second step, management resource was further traced from the aggregate costs in the process to the consuming activity.

The administrative support resource was split up and traced to activities by the cost driver-percentage of employees. Administrative support was determined to correlate with the number of employees since administrative support dealt mostly with payroll. For example, if an activity had one employee and the total number of employees in the distribution center was 13, then the cost driver used to trace administrative support to the activity cost pool would be approximately 8 percent (1/13) of the administrative support resource cost. Note also, with this resource and all others in this model, the administrative support resource was first traced to the appropriate process and then to the appropriate activity cost pool.

As seen in Figure 13, the first-stage cost driver for facility costs traced resource costs to activities based on the percentage of facility space that the activity consumed. The utilities resource used the cost driver of actual usage. For example, the cost of electricity used by a particular activity was traced to that activity. The data systems/computer support resource was traced to activities with a first-stage cost driver based on actual percentage of data systems/computer support used. The equipment maintenance resource was traced to activities with a first-stage cost driver based on the percentage of work-orders completed in for the activity.

Finally, unit and batch level resources (workers, supervisors, equipment) were traced to activities based on the number assigned to the activity. For example, if one

worker ($4,800) and one forklift ($3,575) was required in one activity, the total cost of $8,375 would be traced to the activity's unit/batch level cost pool. Supervisors were traced in slightly different manner. One supervisor was responsible for a different process in the distribution center (e.g., Receiving, Storage, Packing, and Shipping). Each supervisor dedicated a certain amount of time to each activity. For example, if a supervisor dedicated 10 percent of his/her time to a particular activity, $800 (10 percent multiplied by $8,000) would be traced to the activity's unit/batch level cost pool. These unit and batch level resources are the direct costs associated with a particular activity.

A final note about tracing of resources to activities is that all resources were not consumed by the activities considered in the ABC model-activities which specifically dealt with the handling, movement, and storage of distributed materials.. In reality, resources would be consumed and aggregated into other organizational activities that were not considered in this ABC model. Examples of other organizational activities which would also consume resources are activities such as generating distribution cost reports, training of workers, and other activities outside the scope this ABC model. This should be apparent by looking at the ABC model in Appendix B, noting some resources are traced to "Other Departments."

To provide the reader with specific examples, the tracing of resources to the activities of Pallet In-check, Pallet Storage, and Pallet Processing are described.

The management resource was traced to Pallet In-check, Pallet Storage, and Pallet Processing by first tracing the resource costs to each activity's respective process with the first-stage cost driver-percentage of time allocated. It was first determined that

management allocated 12 percent of their time to the Receiving process, 33% to the Storage Process and 12 percent to the Packing Process. Each percentage time allocated cost \$2,784, \$7,656, and \$2,784 for Receiving, Storage, and Packing, respectively. After this first step, the resource costs aggregated within each process was then allocated to each activity. In the Receiving process, management allocated 12.5 percent of their time to the Pallet In-check activity. Thus, \$384 of the management resource was allocated to the Pallet In-check activity for the two-month period. Allocation of management resource costs to Pallet Storage and Pallet Processing activities was conducted in a similar manner and each activity was allocated \$1,278.55 and \$1,392, respectively, for the two month period. Similar steps were used to allocate the resource costs of Administrative Support, Facility Costs, and Utilities, as well as the process-level resources of data systems/computer support and maintenance. The reader should also note that the allocation of all resource costs to all activities is detailed in the ABC model provided in Appendix B.

Unit and Batch level resource were allocated to these activities in a slightly different manner. Worker resource costs were allocated directly to the activities with required the performance of a worker. Note that each worker is a resource that costs \$4,800 for two months. The Pallet In-check activity used one worker and was allocated \$4,800 for the two-month period. Pallet Storage did not require a worker and was allocated no worker costs over the two-month period. Similar to Pallet In-check, the Pallet Processing Activity required one worker and was allocated \$4,800 as well. With respect to equipment, each activity that required a forklift, in-check station, or pallet jack,

was allocated the appropriate two-month capital costs for the respective piece of equipment used. Both the Pallet Storage and Pallet Processing Activities either of these pieces of equipment, thus, were not allocated equipment capital costs in this hypothetical ABC model. However, the Pallet In-check activity required the use of a manually operated computer station to in-check pallets. The capital cost for one manual in-check station was defined to be $4,000 for the two-month period. Thus, the $4,000 was allocated to the Pallet In-check activity.

Step 4. Trace Activities to Organizational Products

Step 4 deals with the second stage of ABC's two stage cost assignment process as described by Beaujon and Singhal (Beaujon and Singhal, 1990:52). During this segment of the ABC process, resource costs, already traced and aggregated into activity cost pools during Step 3, are traced from the cost pool to products and services with second-stage cost drivers. As previously mentioned, the objective of this research is not to develop an ABC model to determine product costs. The objective is to develop a model that facilitates the management of activities. However, second-stage cost drivers are still necessary to determine the costs of resources used when a particular activity has been performed over a certain time period.

Information Needed (Step 4)

The information needed to complete Step 4, includes having all resource costs allocated to the consuming activities. This was accomplished in Step 3 above. Next, appropriate second-stage cost drivers are chosen with the help of distribution center managers and other experts, such as employees in specific activities. When selecting appropriate second-stage cost drivers, certain issues must be considered. That is cost drivers must be chosen with consideration of the cost of measuring the cost driver, the correlation between the cost driver and actual consumption, and the behavior that the cost driver induces (Cooper, 1989:45).

Model Development (Step 4)

In this model, second-stage cost drivers were developed to measure the cost of throughput time for each activity as distributed materials passed through the activity. Cooper stated that certain desired behaviors can influence the selection cost drivers. For example, Cooper mentions that throughput time can be used as a cost driver in just-in-time environments (Cooper, 1989:43). A cost driver, measuring throughput time, allocates costs based on the length of time an activity is performed. Thus, the shorter the length of time an activity is performed, the lesser amount of costs allocated. On the other hand, the longer the length of time, the greater the amount of costs allocated. Cooper contends use of throughput cost drivers induces the behavior to reduce activity performance time. Cooper also mentions, however, that measurement of throughput cost drivers can become very costly, but he notes information systems, increasingly used in

organizations today, can cheaply record throughput cost drivers (Cooper, 1989:43). Furthermore, computer simulation models primarily measure the length of time an activity occurs each time that activity is performed (i.e., throughput cost drivers are inherently measured and reported in computer simulation models). In this hypothetical distribution center, reduction in throughput times of distributed items is sought. Thus, this ABC model uses throughput cost drivers, generated with output data taken from the simulation model, to allocate the costs of activities used in the distribution center.

Total resource costs allocated to Pallet In-check, Pallet Storage, and Pallet Processing in Step 3 are presented in Table 2 by class level.

Table 2: Resource Cost Allocation to Activities

	Pallet Incheck	Pallet Storage	Pallet Processing
Facility Level	$ 3,144.00	$ 24,828.55	$ 12,292.00
Process Level			
Computer Support	$ 1,500.00	$ 3,750.00	$ 1,200.00
Equipment Maint.	$ 930.56	$ 620.37	$ 3,101.85
Unit/Batch Level	$ 9,600.00	$ 1,440.00	$ 7,600.00

The process level costs were not combined so as to provide more cost detail by distinguishing activity computer support costs from equipment maintenance costs. Second-stage cost drivers were then calculated for each class. Pallet In-check had 320 hours (8 weeks at 40 hours per week) available for the two-month period analyzed in the simulation model and in this ABC model. The facility level costs, each process level

cost, and unit/batch level costs were divided by the total hours available (320) for the two months. This provided a cost per hour for each class level. For the Pallet In-check activity, the facility level cost driver was calculated at \$9.83 per hour of Pallet In-check activity, the process level cost drivers for Data systems/Computer support and Equipment maintenance were calculated at \$4.69 and \$2.91, respectively, and the unit/batch level cost driver was calculated at \$30 per hour (see Table 3).

Table 3: Pallet In-check Activity Cost Driver Calculation

	Pallet Incheck	Hours Avail.	Cost Driver (\$/hr)
Facility Level	\$ 3,144.00	320	\$ 9.83
Process Level			
Computer Support	\$ 1,500.00	320	\$ 4.69
Equipment Maint.	\$ 930.56	320	\$ 2.91
Unit/Batch Level	\$ 9,600.00	320	\$ 30.00

Note that the unit/batch level costs include worker salaries (\$4,800), the capital costs of the manually operated computer in-check station (\$4,000) and 10 percent of the receiving supervisor's time (\$800). The reasoning for separating the cost drivers by class level is to provide the manager with a better understanding of how costs are allocated in the Pallet In-check activity (Beaujon and Singhal, 1990:70-71). If all costs (i.e., facility, process, and unit/batch) were combined and traced to the Pallet In-check activity, the total activity cost would be recognized in only one cost figure (\$15,174.56). This figure would be divided by 320 hours and the resulting throughput cost driver for Pallet In-check would be \$47.42 per hour of activity. This combined cost driver would not

indicate to the manager which resource costs (i.e., facility, process, unit/batch) were contributing to the activity cost.

The Pallet Processing activity cost drivers were calculated in the same way as Pallet In-check. The cost figures and cost drivers are seen below in Table 4.

Table 4: Pallet Processing Activity Cost Driver Calculation

	Pallet Processing	Hours Avail.	Cost Driver ($/hr)
Facility Level	$ 12,292.00	320	$ 38.41
Process Level			
Computer Support	$ 1,200.00	320	$ 3.75
Equipment Maint.	$ 3,101.85	320	$ 9.69
Unit/Batch Level	$ 7,600.00	320	$ 23.75

The second-stage cost drivers for Pallet Storage were computed in a slightly different manner. Pallet Storage contained 100 pallet storage locations and each location was available for 320 hours also. To calculate the cost drivers, the total costs, traced to the activity, were divided by 320 hours and then divided by 100 locations. This provided the hourly costs necessary to store a pallet in each location. Table 5 below shows the details of these cost calculations and figures. The pallet storage cost figures in the table indicate it costs 78 cents per hour of facility level costs to store a pallet, 12 cents and 2 cents per hour to provide computer support and maintenance, respectively, and 5 cents per hour for storage supervision.

Table 5: Pallet Storage Cost Driver Calculations

	Pallet Storage	Hours Avail.	Storage Locations	Cost Driver ($/hr)
Facility Level	$ 24,828.55	320	100	$ 0.78
Process Level				
Computer Support	$ 3,750.00	320	100	$ 0.12
Equipment Maint.	$ 620.37	320	100	$ 0.02
Unit/Batch Level	$ 1,440.00	320	100	$ 0.05

For each of the activities in the ABC model, simulation data was generated. Simulation data provided: 1) the average amount of time (i.e., throughput time) that each activity required when performed; and 2) the total number of distributed items that were processed through each activity. These figures (activity throughput time and number of items through each activity) were multiplied together to determine the amount of time each activity was used during the two-month period. For example, the Pallet In-check activity required, on average, 2.34 minutes to in-check a pallet. This equates to .039 hours to in-check a pallet. The number of pallets in-checked over the simulated two-month period was determined to be approximately 3,571 pallets. Multiplying the number of pallets times the average length of time required to in-check a pallet provides the amount of time the activity performed over the two-month period. This was calculated to be approximately 139.3 hours. Next, the total time (139.3 hours) was multiplied by the cost drivers in the Pallet In-check activity. The cost drivers were associated in costs per hour, so calculating the cost driver multiplied by the total number of hours generates the total costs used to perform the Pallet In-check activity over the two month period. The

used cost figures can be seen below in Table 6. The used cost figures for Pallet Storage and Pallet Processing are provided in Tables 7 and 8, respectively, below. Similar calculations were made for all activities in the ABC model of current distribution center.

Table 6: Calculating Pallet In-check Activity Costs Used for Two Months

Pallet In-check Activity	Cost drivers $/hr	Time Performed	Cost of Activity Used
Facility Level	$ 9.83	139.3	$ 1,369.32
Process Level			
- Computer Supt	$ 4.69	139.3	$ 653.32
- Equipment Maint	$ 2.91	139.3	$ 405.36
Unit/Batch Level	$ 17.50	139.3	$ 2,437.75

Table 7: Calculating Pallet Storage Costs Used for Two Months

Pallet Storage Activity	Cost Drivers $/hr	Time Performed	Cost of Activity Used
Facility Level	$0.776	27543.407	$21,370.72
Process Level			
- Computer Support	$0.117	27543.407	$3,227.74
- Equipment Maint	$0.019	27543.407	$533.97
Unit/Batch Level	$0.045	27543.407	$1,239.45

Table 8: Calculating Pallet Processing Activity Costs Used for Two Months

Pallet Processing Activity	Cost Drivers $/hr	Time Performed	Cost of Activity Used
Facility Level	$38.41	200.17	$7,689.18
Process Level			
- Computer Support	$3.75	200.17	$750.65
- Equipment Maint	$9.69	200.17	$1,940.34
Unit/Batch Level	$23.75	200.17	$4,754.13

Construction of an ABC Usage Statement

Cooper and Kaplan discussed how ABC models are used to estimate the costs of resources used in organizational activities to produce outputs, such as services or products. With ABC resource usage cost information, managers are able to pinpoint activities for cost reduction (Cooper and Kaplan, 1992:2).

The measurement of unused capacity provides the link between the costs of resources used and the cost of resources available for each organizational activity considered. ABC measures the costs of resources used while DoD cost codes provide the cost of resources available to activities. Cooper and Kaplan give the following equation, for each individual activity, to formalize the relationship between activity availability and activity usage (Cooper and Kaplan, 1992:1):

Activity Availability = Activity Usage + Unused Capacity

The ABC model in this research was developed to provide activity usage costs for comparison with activity resource availability and unused activity costs. As was

determined in Step 3 of ABC model development, overall distribution center resource costs were identified and traced to activities with the use of first-stage cost drivers. This step determined the amount of resource costs aggregated within each activity, hence, the resource availability in each activity. Step 4 of ABC model development determined the cost of activities used. Thus, the data necessary to calculate the ABC usage statement are available.

For example, again using the Pallet In-check activity, information on activity resource availability, activity used, and activity unused are compared to determine the capacities of each activity and the costs associated with an ABC usage statement. Resources available in the Pallet In-check activity were calculated and determined to be: \$3,144 in facility level costs (e.g., facility management, administration, costs, utilities); \$1,500 in computers support costs; \$930.56 in equipment maintenance costs; and \$5,600 in unit/batch level costs (e.g., worker, computer in-check station, and supervisor). The activity usage costs, calculated from simulation model data and second-stage cost drivers, were determined to be: \$1,369.32 in facility level costs; \$653.32 in computer support costs; \$405.36 in equipment maintenance costs; and \$2,437.75 in unit/batch level costs. The usage costs were subtracted from the available resource costs to provide activity costs unused. Finally, the percentages of activity used and unused were calculated. See Table 9 for details.

Table 9: Percentage of Available Pallet In-check Activity Used in Two Months

Pallet In-check Activity	Cost of Activity Avail	Cost of Activity Used	Cost of Activity Unused	% of Activity Used	% of Activity Unused
Facility Level	$ 3,144.00	$1,369.32	$ 1,774.68	43.6%	56.4%
Process Level					
- Computer Supt	$ 1,500.00	$653.32	$ 846.68	43.6%	56.4%
- Equipment Maint	$ 930.56	$405.36	$ 525.20	43.6%	56.4%
Unit/Batch Level	$ 9,600.00	$4,178.93	$ 5,421.07	43.5%	56.5%

See Tables 10 and 11 below for the ABC usage statements for Pallet Storage and Pallet Processing activities, respectively.

Table 10: Percentage of Available Pallet Storage Used in Two Months

Pallet Storage Activity	Cost of Activity Avail	Cost of Activity Used	Cost of Activity Unused	% of Activity Used	% of Activity Unused
Facility Level	$ 24,828.55	$ 21,370.72	$ 3,457.84	86.1%	13.9%
Process Level					
- Computer Support	$ 3,750.00	$ 3,227.74	$ 522.26	86.1%	13.9%
- Equipment Maint	$ 620.37	$ 533.97	$ 86.40	86.1%	13.9%
Unit/Batch Level	$ 1,440.00	$ 1,239.45	$ 200.55	86.1%	13.9%

Table 11: Percentage of Available Pallet Processing Activity Used in Two Months

Pallet Processing Activity	Cost of Activity Avail	Cost of Activity Used	Cost of Activity Unused	% of Activity Used	% of Activity Unused
Facility Level	$ 12,292.00	$ 7,689.18	$ 4,602.82	62.6%	37.4%
Process Level					
- Computer Support	$ 1,200.00	$ 750.65	$ 449.35	62.6%	37.4%
- Equipment Maint	$ 3,101.85	$ 1,940.34	$ 1,161.51	62.6%	37.4%
Unit/Batch Level	$ 7,600.00	$ 4,754.13	$ 2,845.87	62.6%	37.4%

With this information on activity usage, managers can determine both the capacity and the costs associated with individual activities, potentially highlighting activities that might warrant management attention.

Finally, the simulation model of the current DC operation (Current Model) was altered to include advanced cross-docking techniques (Altered Model). New simulation data was generated from the Altered Model, including altered activity throughput times and altered numbers of items processed through the activities. The data from the altered simulation model was then input into the ABC model. Changes in costs and activity usage were sought by comparing the ABC information from the Altered Model to the ABC information of the previous Current Model. These comparisons are made and analyzed in Chapter Four.

IV. Analysis of Results and Discussion

Overview

In this chapter the results of the simulation experiments and ABC model calculations are discussed. The authors deem it important to emphasize the results are just as hypothetical as the models that generated them. The focus here, as in Chapter Three, was to propose a framework for building a decision support tool. Chapter Four adds to this proposed framework by using the results from the simulation and ABC models to illustrate the types of information potential users may expect to obtain from such a costing and performance measurement tool. Also, the possible implications of having such information will be discussed.

Time Performance Analysis of the Current and Altered Models

The ensuing analysis will be performed in light of DoD's logistics goals of reducing cycle times, developing a seamless logistics system, and streamlining logistics infrastructure (DoD, 1996/1997:15-29). The DLA's distribution centers use some cross-docking strategies. However, they may not be operating as efficiently and effectively as they could using the most advanced cross-docking distribution methods employed in the commercial sector. To continue with the present study's goal of proposing a framework for building a decision support tool, the following analyses illustrate how computer simulation modeling of current military DC operations and those incorporating advanced

cross-docking methodologies could help military logistics managers make decisions to help meet DoD logistics goals.

Summaries of the activity time statistics are provided in Appendix A for the Current and Altered models. These statistics were used as inputs to the ABC model, but also can be used as part of a time performance analysis. Summaries of the activity await times are also shown in Appendix A. These statistics were taken specifically for time performance analyses of the two models. Table 12 below provides a combined time statistics comparison of the Current and Altered Models.

Activity performance and await times for the storage process were not included in this table or time performance analysis—portions of the storage process are included in the cost performance analysis in the ABC section of this chapter. Rather, only those activities and their respective await times comprising the direct flow of materials from receiving through shipping are included in Table 12 for time performance analysis. In the table, await times can be identified in rows whose description begins with the word "Await." All other times are the average time it took each respective activity to process the items through activity stations. Items sat idle awaiting activity processing while the activity resource was busy on other items. This waiting time is part of the total time it takes to move materials from inbound trucks to outbound trucks. Thus the time performance of the two models will be discussed in terms of total inbound to outbound time (for items not bound for or coming out of storage) and the impact of changes in individual activities times on the total time as a result of the four cross-docking modifications described in Chapter Three.

Table 12: Combined Time in System Summary Statistics

Row	Times are in minutes Activity Description	Flow Path 1: Bin Item (convey) Current	Altered	Save	Flow Path 2: Bin Item (tow) Current	Altered	Save	Flow Path 3: Unitized Pallets Current	Altered	Save
1	Await receiving super	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	Supervisor signs BOL	9.4	9.5	-0.1	9.4	9.5	-0.1	9.4	9.5	-0.1
3	Await unload	16.0	16.4	0.0	16.4	16.4	0.0	16.4	16.4	0.0
4	Unload trucks	2.0	2.0	0.0	2.0	2.0	0.0	2.0	2.0	0.0
5	Await breakdown worker	1.6	1.0	0.6	1.6	1.0	0.6	1.6	1.0	0.6
6	Breakdown conveyables	0.3	0.3	0.0			0.0			0.0
7	Breakdown towables				1.0	1.0	0.0			0.0
8	Ld pallets onto TLC1						0.0	3.0	3.0	0.0
9	Conveyables to bin receipt	3.0	3.0	0.0			0.0			0.0
10	Await bin receipt	26.8	0.0	26.8			0.0			0.0
11	Bin Receipt	1.5	0.0	1.5			0.0			0.0
12	Conveyor to build up	7.0	7.0	0.0			0.0			0.0
13	Tow line to pallet receive				7.0	7.0	0.0	7.0	7.0	0.0
14	Await pallet receipt				3.6	0.0	3.6	3.6	0.0	3.6
15	Pallet Receipt				2.3	0.0	2.3	2.3	0.0	2.3
16	Tow line to build up				7.0	7.0	0.0			0.0
17	Await build up	4.4	9.8	-5.4	4.4	9.8	-5.4			0.0
18	Triwall build up	1.8	1.8	0.0	1.8	1.8	0.0			0.0
19	Towline to plt proc/consol						0.0	9.0	9.0	0.0
20	Towline fm buildup to plt prc	7.0	7.0	0.0	7.0	7.0	0.0			0.0
21	Await pallet processing	4.5	0.1	4.4	4.5	0.1	4.4	4.5	0.0	4.5
22	Process pallets for ship	5.0	5.0	0.0	5.0	5.0	0.0	5.0	0.0	5.0
23	Towline fm plt proc to cons	7.0	7.0	0.0	7.0	7.0	0.0			0.0
24	Await consolidation	1.2	12.0	-10.8	1.2	12.0	-10.8	1.2	12.0	-10.8
25	Forklift pallets to cons	5.0	5.0	0.0	5.0	5.0	0.0	5.0	5.0	0.0
26	Await loading into trucks	153.5	157.3	-3.8	153.5	157.3	-3.8	153.5	157.3	-3.8
27	Load outbound trucks	5.0	5.0	0.0	5.0	5.0	0.0	5.0	5.0	0.0
28	Await shipping supervisor	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.0
29	Shipping super do BOL	14.3	14.3	0.0	14.3	14.3	0.0	14.3	14.3	0.0
30	Total Path Flow Times:	276.4	263.6	**13.2**	259.1	268.3	**-9.2**	242.9	241.6	**1.3**
31	Percent savings in Time:	**4.8%**			**-3.6%**			**0.5%**		
32	Total time w/o consol:	116.7	89.3	27.4	99.4	94.0	5.4	83.2	67.3	15.9
33	Percent Savings w/o Consol:	**23.5%**			**5.4%**			**19.1%**		

Overall Time Performance

The Current Model, simulating a hypothetical existing DC operation, took an average 276.4 minutes to process a conveyable bin item from inbound truck to outbound truck. Simply knowing this time can be of value to a manager. However, via on site visits to the CCP the authors learned CCP managers had no way to track the time it took

to process each item through the facility. The difficulty is inherent in the break down and build up processes. When a palleted tri-wall comes in from a truck, time tracking for that particular pallet could begin. Then, in the case where binnable items with different destination addresses must be broken out of the tri-wall, time must be tracked for each bin item coming out of the tri-wall. This could be added to the tri-wall's current processing time, to continue tracking total DC time for each bin item. The time tracking problem begins when bin items are combined in tri-walls, and then the tri-walls are consolidated in the shipping process until enough build up for one destination to fill a shipping container (sea van or truck load). At each of these two build up stages the individual items become assigned to "lead lines" (first item into a tri-wall or highest priority item into a tri-wall) and can no longer be individually traced (Taylor, 1996). These challenges may possibly be overcome by using a computer simulation model to learn the mean await and activity processing times, and adding them for all await stations and activities in the DC process along each flow path. With a simulation model estimate of item processing times in hand, a manager can then alter the model to explore ways to improve performance.

Flow Path One

There were three basic flows of material through the hypothetical DCs. The first flow (Flow Path 1 in Table 12) was the path taken by bin items small enough to fit on the gull-wing conveyor. In the Current Model, total flow time for Flow Path 1 was 276.4 minutes. The cross-docking changes reduced this to 263.6 minutes in the Altered Model.

This represents only a 4.8 percent reduction in flow time. The largest cause of change was the reduction in time items spent waiting for receipt from 26.8 to zero minutes, due to a combination of the replacement of bin in-check workers with automatic scanners and the reduction in percentage of inbound pallets needing break-bulk. These changes also dropped bin in-check time from 1.5 minutes to zero. However, this flow-through at the bin receive station caused a growth in the await build-up queue, causing the await times there to increase 5.4 minutes in the altered model.

Since the Altered Model allowed more pallets to bypass pallet processing, the Altered Model showed a 4.4 minute time savings at pallet processing for Flow Path 1. The overall effects of the above changes in the system, combined with an increase in percentage of items flowing directly through the DC (reduced inventory), caused two offsetting time increases in the shipping process of Flow Time 1. Note, on lines 24 and 26 of Table 12, the -10.8 and -3.8 minute "savings" (time increases) in Flow Time 1. Basically, the faster flows in the DC due to cross-docking alterations caused larger material pile-ups in the shipping area.

This Flow Time 1 analysis is an excellent illustration of how simulation modeling can show managers the affects of changing processes and activities, without having to interrupt the real world system. It is also an example of how the proposed performance measurement tool can suggest possible changes in the DC. For example, managers may consider the 4.8 percent improvement as support for a decision not to implement cross-docking.

Alternatively, a manager may use these results to consider further modifications to the DC to attain better flow times. For instance, if the consolidation steps in Flow Time 1 were eliminated, a total flow time savings for conveyable bin items could be improved to 23.3 percent, as shown in the last two rows of Table 12. Thus, the simulation tool may be used iteratively to test simple observations and hypotheses, such as this consolidation elimination idea. Here, now, a manager may have to find a way to load pallets onto trucks as soon as they arrive into the shipping area on tow-line carts. This may imply trucks would have to be pre-scheduled and waiting and/or more and smaller trucks are needed. This also may simply push an inventory bottleneck to the next place in the logistics supply chain.

Another logistics alternative suggested by the build up of materials in the shipping section in the models may be to consolidate DCs. This, like the cross-docking methodologies of pre-labeled packages and unitized pallet loads, requires managers to look beyond the walls of DCs for optimal engineering of the logistics supply chain. High technology cross-docking methods already employed by the DLA, such as automated conveyors and advanced shipping notices, combined with those used in this thesis and others available, may smooth and speed flows through DCs and increase one DCs capacity enough to handle a consolidation of several DCs. In this way, truck loads would be created faster at the shipping process and materials could be shipped out sooner. Notice (line 26 of Table 12) the time pallets spend consolidating to make a full truckload consumes over 50 percent of the DC flow through time for all three flow paths in both Current and Altered Models. This may represent a significant portion of the logistics

cycle time in a supply chain. The consolidation option created by efficient materials cross-docking could allow the DoD to eliminate several DCs, streamlining and leaning logistics infrastructure.

Flow Path Two

Flow Path 2 represents the path bin items too large to fit on the gull-wing conveyor take through the hypothetical DC. They must ride tow line carts everywhere, just as do full pallets. These items actually took longer to get through the Altered DC primarily due to the pile up in the shipping area described above. Some time savings were achieved by the replacement of the pallet receipt worker by an automatic scanner, but the overall system changes resulted in tow line bin items taking 3.6 percent longer when the cross-docking methodologies were introduced into the system. One consideration not shown by Table 12 is the relative numbers of items flowing along the three paths. Only five percent of the bin items are defined in the models to be too large to fit on the gull-wing conveyor. Thus the time changes for Flow Path 2 may be given negligible consideration by the manager in her or his final decision whether or not, and how, to modify the DC.

Flow Path Three

Unitized pallets (those not requiring break down into bin items) move along Flow Path 3. Replacing the pallet in-check worker with a scanner resulted in a 5.9 minutes

savings (3.6 minutes awaiting pallet in-check and 2.5 minutes being in-checked were eliminated). Pre-processing the pallets (allowing them to skip pallet processing) created a 9.5 minutes savings between awaiting and moving through pallet processing. However, as in the other two flow paths, 14.6 minutes were added to the flow times in the consolidation steps. The time savings and losses approximately canceled each other out, resulting in an overall .5 percent time savings. Notice, as in Flow Path 1, the significant time savings (19.1 percent in this case) possible by eliminating the consolidation steps. This may give the manager further incentive to explore the DC consolidation or eliminate pallet consolidation options described earlier.

Limitations of Flow Time Analysis

One important point must be made about the above time performance analysis. The flow times calculated were created by piecing together individually measured await and activity process times to get past the difficulty of tracking every item through the DC individually. Such tracking is logistically difficult, as evidenced by the CCP tracking challenges described earlier, and consumes prohibitive quantities of file space in a simulation run, as discovered by the authors upon initial attempts to do so. The point here is that one can get an idea how long it takes items to flow along the several paths of a DC using the above proposed time analysis. However, this does not provide a feel for the resource utilization changes or time savings created by incorporating the several cross-docking methodologies.

For example, consider the total flow times for a bin item in the Current Model (276.4 minutes) and a unitized pallet in the Altered Model (241.6 minutes). Recall one of the cross-docking methodologies introduced into the Altered Model was to coordinate with shippers an increase in the percentage of pallets coming off trucks to be in pre-unitized form (all pallet contents bound for same location and the pallet pre-weighed, pre-wrapped, pre-dimensioned, pre-labeled, etc.). The authors changed this from 80 percent pre-*palletized* to 90 percent pre-*unitized*, to simulate the supply chain coordination. That is, in the Current Model 80 percent of the pallets coming out of an inbound truck did not require break down into bin items, but still needed to go through the pallet processing station in the DC, since they were not pre- weighed, wrapped, etc. Conversely, this meant only 10 percent of the pallets introduced into the Altered Model were tri-walls of items bound for different destinations (requiring break-down and re-build up into unitized tri-wall pallets), compared to 20 percent in the Current Model. This is evidenced by comparing the number of items processed at bin in-check and pallet in-check in the two models. In the Current Model, 8,323 items (average across 15 runs) were processed through bin receiving, as opposed to only 3,633 bin items (4,690 less) in-checked in the Altered Model (see Appendix A). Alternatively, 3,312 pallets were in-checked in the Current Model as opposed to 3,572 (260 more) pallets in the Altered Model. This means the Altered Model handled far fewer items than the Current Model.

The time dimensions implied by these savings are not easily identified, due to the time tracking difficulties inherent in break down, sortation, and build up, as previously explained. However, the ABC model proposed below captures the significance of the

reductions in items handled in the resource utilization statistics, and the costs associated with the differences between the two models in used resource capacities.

One indication of savings can be made intuitively, though: The 4,690 extra items processed as conveyable bin items in the Current Model took 276.4 minutes to flow through Path 1. These same items, in effect, flowed through the altered model inside the additional 260 pre-unitized pallets (an average of about 18 bin items per unitized pallet) in only 241.6 minutes through Path 3 of the Altered Model. The material flow time for these items in the Current model was 4,690 multiplied by 276.4 minutes (1,296,316 minutes or 21,605.27 hours). The material flow time for those items in the Altered Model was 260 multiplied by 241.6 minutes (62,816 minutes or 1,046.9 hours). Thus the cross-docking modifications produced a material flow time savings of over 20,000 hours. The costs of more advanced cross-docking technology investments, in the eyes of a manager, may or may not be justified by these material flow savings. Again, the savings are not readily identifiable with the flow time analysis, but a proposed framework for capturing and comparing the time/cost tradeoffs is presented in the ABC analysis below via resource utilization calculations and related used capacity.

Cost Performance Analysis of the Current and Altered Models

This section provides an activity costing analysis of outputs derived from the decision support tool developed within this research. The outputs from the decision support tool are provided for both the Current DC Model and Altered DC Model, facilitating activity usage and cost comparisons. To simulate implementation of

advanced cross-docking techniques, the Altered Model was constructed to contain four key differences than the Current Model. First, the Current Model used two workers and two manual in-check computer stations to receipt incoming binnable items and pallets. The Altered Model changed this in-check procedure by removing and replacing both the in-check workers and manual in-check stations with automatic in-check scanners, suggesting the implementation of advanced cross-docking technology. Second, the Current Model simulated the storage of 60 percent of all incoming items into the DC. The Altered Model simulated the storage of 40 percent of the incoming items into the DC, suggesting increased usage of cross-docking. Third, the Current Model simulated that 80 percent of all pallets coming into the Current DC were cross-dockable (i.e., the pallets did not require breakdown and moved through the DC to shipping). The Altered Model simulated that 90 percent of all pallets were cross-dockable. Fourth, the Current Model required that all pallets, once in-checked into the DC, must be processed through the Pallet Processing activity for outbound shipment. The Altered Model simulated that all cross-dockable pallets, once automatically in-checked, could by-pass the Pallet Processing activity since all pallet processing and labeling activities, required for outbound shipment from the DC, had already been accomplished by a shipper back up the supply chain. This is another example of using cross-docking techniques.

This research proposed a framework for developing a decision support tool that might assist DoD DC managers in their abilities understand particular activity costs and to weigh the alternatives of implementing advanced cross-docking techniques into a DoD DC. The decision support tool was developed by combining computer simulation with

Activity-Based Costing. The four key differences between the Current and Altered models were first modeled and compared with computer simulation. The computer simulation models provided performance outputs for all activities in both the Current and Altered DC models. These performance outputs were then input into the developed Activity-Based Costing (ABC) model. The ABC model provided activity usage statements for both the Current and Altered DC models. These activity usage statements, described in detail in Chapter Three, elicit specific activity usage and associated cost figures, highlighting certain activities that have drastically changed with respect to activity usage and cost. Using the outputs derived from the decision support tool, this section will analyze the implementation cross-docking into a DoD DC, comparing changes in total DC costs, changes in activity usage and costs, and changes in direct material costs.

There are two primary differences in total cost structure between the Current and Altered models. The Current Model uses two manually operated in-check stations each with one worker. There is one manually operated in-check station for binnable items and one for pallets. The capital costs for using the manual in-check stations over a two-month period were calculated to be $4,000 each for a total capital cost of $8,000. Worker costs associated with operating the in-check stations amounted to $9,600. That is each worker's labor cost amounted to $4,800 for the two-month period. By comparison, the Altered Model used automatic in-check scanners in place of the manual in-check stations. This resulted in a reduction in labor costs of $9,600 since workers were no longer necessary. However, the new automatic in-check scanners had higher two-month capital

costs. Each scanner had a two-month capital cost of $8,000 each for a total cost of $16,000. Note that other than worker resources, all other resources, such as Data Systems/Computer Support, were traced to the Bin and Pallet In-check activities with the same percentages in both the Current and Altered models. Finally, the decision tool was able to calculate the total operating costs for both models. Total DC operating costs for the Current Model were calculated to be $414,600 for the two-month operating period. On the other hand, total DC operating costs for the Altered Model were calculated to be $413,000 for the two-month period. Even though the calculated savings of implementing advanced technology was only $1,600 and not significant considering the overall costs, the point here is to show the kinds of information that this proposed decision support tool may provide.

To illustrate the differences in activity usage and costs between the Current and Altered models, activity usage statements were generated for both models. Activity usage statements and summary statistics are provided in Appendix B. For ease of reference, Tables 13 and 14 are provided on page 170 to illustrate the activities that changed significantly from the Current Model to the Altered Model. Many of the activities, however, did not show a significant change in usage. This suggests cross-docking modifications had no effect on the amount distributed materials as well as the length of time that these materials were processed through certain activities. For example, the percentage of available resources used by the forklift driver unloading the trucks in the receiving section changed only from 74.2 percent to 74.6 percent. Such a small change is not explainable by the tool, and likely is a result of minor random error

fluctuations between the two models. However, this result makes sense from a practical standpoint. That is, none of the cross-docking modifications made to the first model should result in a change to the number of pallets the forklift driver would have to unload, since no changes were made to the numbers or timing of truck arrivals or number of pallets on each truck. Also, since the length of time required to unload the trucks did not change, the amount of resources used by the unloading activity did not change significantly between the two models. This common sense approach can be used to see why many activities did not show a significant change in the percentage of available resources they consumed.

Several activities did show a significant changes and can be seen in Tables 13 and 14 on page 170. Note that more detailed activity usage statements are available in Appendix B. For example, the tool showed that the percentage of available resources used by the Bin In-check (R.3.2) and Pallet In-check (R.3.4) activities changed considerably as a result of replacing manual in-check stations with automatic in-check scanners.

Table 13: Summary Activity Usage Statement for Current Model

ABC Activity Code	Description of Activity/Event	Activity Avail ($)	Activity Used	% Act. Used
R.3.2	Bin Inchecker input binnables into computer syst.	14576.56	9478.41	65.0%
R.3.4	Pallet inchecker input pallets into computer system	15174.56	6605.56	43.5%
S.1.1	Place binnables into bin storage	13593.59	6589.21	48.5%
S.1.2	Storage of binnables	26605.86	17647.35	66.3%
S.1.3	Pick binnables from bin storage	13053.22	8496.95	65.1%
S.2.1	Place "palleted" items into pallet storage	16548.22	9193.40	55.6%
S.2.2	Storage of "palleted" items	30638.92	26371.88	86.1%
S.2.3	Pick "palleted" items from pallet storage	17248.59	10859.60	63.0%
P.1	Pack triwall cartons with bin and "palleted" items	24793.85	13200.87	53.2%
P.3	Pallet processing activity	24193.85	15134.30	62.6%

Table 14: Summary Activity Usage Statement for Altered Model

ABC Activity Code	Description of Activity/Event	Activity Avail ($)	Activity Used	% Act. Used
R.3.2	GW/Auto-Scan binnables into computer syst.	13422.27	152.39	1.1%
R.3.4	Auto-Scan pallets on TLC into computer system	14020.27	145.14	1.0%
S.1.1	Place binnables into bin storage	13639.31	2196.07	16.1%
S.1.2	Storage of binnables	26628.72	5913.44	22.2%
S.1.3	Pick binnables from bin storage	13098.94	2847.54	21.7%
S.2.1	Place "palleted" items into pallet storage	16593.94	6540.98	39.4%
S.2.2	Storage of "palleted" items	30661.78	18495.72	60.3%
S.2.3	Pick "palleted" items from pallet storage	17294.31	7705.16	44.6%
P.1	Pack triwall cartons with bin and "palleted" items	24862.42	6492.67	26.1%
P.3	Pallet processing activity	24262.42	1416.78	5.8%

In the Current Model, the percentage of resources used by the Bin In-check activity were 65 percent and dropped to only 1.1 percent in the Altered Model. Similarly, the Pallet In-check activity's resource usage dropped from 43.5 percent to only 1 percent. Note that even though the percentages of resources used by the Bin and Pallet In-check activities are 65 and 43.5 percent, respectively, and are hypothetical in the Current

Model, these percentages may be reasonable, considering the DoD's strategy of maintaining contingency surge capacities in their distribution centers. Also shown by the tool is the amount of costs associated with resource usage. For example, the Bin In-check activity had $14,576.56 available in resources. A manager can see from the tool that $9,478.41 of resources available were actually used (65 percent). This also shows a manager that $5098.15 of resources available were not used (35 percent), suggesting enough excess capacity for contingency surges.

The reasons for such drastic decreases in activity usage are a result of implementing automatic in-check scanners in place of the manually operated in-check stations. This use of auto-scanning illustrates a key strategy in cross-docking, using advanced technology in coordination with pre-labeled pallets coming from shippers. The time required to manually in-check pallets in the Current Model was 2.34 minutes, on average, per pallet. After implementing the automatic in-check scanners, the time required to in-check a pallet dropped to 3.6 seconds, on average. The number of pallets in-checked remained the same. However, the considerable decrease in the amount of time necessary to in-check a pallet resulted in a decrease in resource usage and a considerable increase in activity capacity available. Thus, using this decision support tool, managers can use actual percentage figures to support their intuition that in-check activity capacity would increase as a result of replacing workers with advanced technologies. Furthermore, the tool also provides managers with related cost figures. Knowing this information may help a manager decide whether or not to make an

investment in automatic scanners and coordinate with shippers to pre-label packages and pallets.

Another comparison between the Current and Altered models shows that the percentage of resources used by activities related to Bin and Pallet Storage also decreased significantly. These reductions, as shown by the decision support tool, are a result of using cross-docking methods to decrease the amount of distributed items required to be placed into storage. With respect to the Current Model, the Pallet Storage activity (S.2.2) used 86.1 percent of available resources. Likewise, the Bin Storage activity (S.1.2) used 66.3 percent of available resources. Compared to the Altered Model, Pallet Storage and Bin Storage resource usage percentages dropped to 60.3 percent and 22.2 percent, respectively. Pallet and Bin storage locations are likely to require a considerable amount of DC space. Thus, these combined decreases in storage space utilization and related costs (e.g., Pallet Storage resources used was $18,495.72 verses $12,166.06 in the Altered Model) might help a manager make decisions, such as whether or not to consolidate several DC storage facilities into one large facility or to move the currently under-utilized facility to a smaller and cheaper facility.

As may be expected in a surge capacity environment, 62.2 percent of the resources available were used by the Pallet Processing activity (P.3) in the Current Model. The tool demonstrated a dramatic reduction in pallet processing expected to be used when pallets are pre-processed for cross-docking as simulated in the Altered Model. Note the decrease in pallet processing activity usage from 62.2 percent to only 5.8 percent. Note that both models, in this experiment, used one pallet processing worker.

Considering the worker is only 5.8 percent used in the Altered model, a manager may use this information to determine the pallet processing activity should be combined with another activity to better utilize workers. If more than one worker were used in the Current Model, a manager may have used the reduction to 5.8 percent use as justification to eliminate one of the job positions in pallet processing or move one or more workers from pallet processing to a more constrained activity in the distribution center.

Finally, besides being able calculate total DC costs and being able to cost specific activities within a DoD DC, the tool also was able to calculate the costs of materials used in the DC. For example the ABC model calculated the material costs for pallets, shrinkwrap material per pallet, labels, triwall cartons, and shipping documents. Material cost were then compared between the Current and Altered models. These costs are shown in Tables 15 and 16 below.

Table 15: Direct Materials Costs for Current Model

	Activity	Unit Cost	Units	Total Cost
Triwall Cartons	P.1: Packing of triwalls	10.00	451	4510.00
Shrinkwrap Mat./Pallet	P.3: Pallet Processing	5.00	451	2255.00
Pallet Lables	P.3: Pallet Processing	0.50	2412	1206.00
Pallets	P.1: Packing of triwalls	15.00	451	6765.00
Outbound Ship Docs.	Sh.2: Generate ship docs	0.50	51	25.67
Total Direct Material Costs				$ 14,761.67

Table 16: Direct Materials Costs for Altered Model

	Activity	Unit Cost	Units	Total Cost
Triwall Cartons	P.1: Packing of triwalls	10.00	225.267	2252.67
Shrinkwrap Mat./Pallet	P.3: Pallet Processing	5.00	225	1125.67
Pallet Lables	P.3: Pallet Processing	0.50	225	112.57
Pallets	P.1: Packing of triwalls	15.00	225	3377.00
Outbound Ship Docs.	Sh.2: Generate ship docs	0.50	52	26.00
Total Direct Material Costs				$ 6,893.90

Costs of these materials used in DC operations over the time of the simulation run dropped from $14,761.67 to $6,893.90 with the incorporation of cross-docking techniques. Note that these cost savings might be pushed back to shippers in a supply chain. However, this example illustrates how the ABC model may be used to calculate virtually all significant costs in the distribution center and how knowing these costs may be used by manager to help make supply chain cost-benefit analyses and decisions. For example, the DC manager may agree to share these material costs with the shippers, in exchange for the preprocessing of distributed items to facilitate cross-docking.

Thus, the primary goal of the decision support tool, other than demonstrating performance changes, was to demonstrate the ability to cost activities and other associated costs, such as material costs. The tool provides managers with accurate cost information, highlighting important cost implications and helping managers in their decisions.

V. Conclusions

Overview

The U.S. government no longer needs large Department of Defense (DoD) budgets, due to the end of the Cold War. This, combined with the intense public scrutiny of the Federal Budget Deficit is forcing the DoD to operate on increasingly reduced budgets. Now, the DoD must focus on operating more efficiently to save money while remaining effective enough to successfully perform its military operations and be prepared for any identified potential threats to national security.

One area of vast potential DoD savings, without sacrificing military effectiveness, is military logistics. Cold War DoD logistics stockpiled as many spare assets as possible. Now, in post Cold War, the DoD cannot afford to waste valuable dollars handling, storing, and maintaining gross stockpiles of spare assets; The DoD must rethink and re-engineer the way it conducts its logistics business. DoD logistics managers have been tasked by its leadership to change from the effective combat support capability strategy of stockpiling to new, more efficient strategies and managerial techniques without any loss in effectiveness. As outlined in Air Force Logistics Management Agency's Megatrends Report, DoD logistics managers should focus their attention upon their private sector counterparts for strategies to operate more efficiently, while retaining or increasing efficiency (AFLMA, 1996). It makes good sense to learn from commercial sector

businesses who fight and win battles of efficiency and effectiveness against their competition everyday.

Private sector industries, such as retail, have drastically shortened pipelines and have implemented "pull" rather than "push" supply chain strategies. These efforts have helped private firms cut inventories and associated holding costs, allowing them to invest in opportunities more profitable than inventory. Two of the ways the private sector has done this is through use of cross-docking and Activity-Based Costing.

The Defense Logistics Agency (DLA), a huge player in DoD logistics, has already taken some ideas from the private sector and put them to use, in response to The DoD's drive to improve efficiency. Some of those ideas include electronic data interchange (EDI) and automated systems within DLA's distribution centers (DC), for more efficient control and handling of materiel distribution. The DLA, however, could further re-engineer its supply chain and shorten pipelines for more efficient and effective performance, with the use of cross-docking and ABC.

The application of cross-docking in DLA would enhance efficiency and effectiveness by reducing inventories, reducing pipeline times, and by transitioning DLA from a push to a pull supply chain. The application of ABC in DoD would aid logistics managers in determining the most cost effective ways to bring about logistics efficiency improvements. But how do DoD logistics managers within DLA know whether or not to implement such commercially successful distribution methodologies as cross-docking? A computer simulation model of a DLA DC may be used, in conjunction with an ABC model, to measure DC cost and time performance. Then the simulation and costing

models could be altered, simulating the application of commercially successful cross-docking techniques within the DC, to more efficiently accomplish the same job as the current real-world system. The models, then, could be used as a decision support tool by logistics managers to determine whether or not to implement cross-docking, and in what form, for the most efficient and effective DC operations.

DLA's closest example of cross-docking is in its Defense Distribution Region East Consolidation Control Point. DLA is in the process of applying ABC to its current distribution processes. However, the current Consolidation Control Point is not taking advantage of all the most advanced cross-docking methodologies and, thus, may be altered to operate more efficiently and effectively. Also, without the aid of a computer simulation model and ABC techniques, it may be very difficult, if not infeasible, to accurately determine the time and cost performance of each activity and process step an item takes flowing through a DLA DC.

Site visits by the authors made it patently clear the DoD possesses the resources to construct a decision support tool as proposed in this research. The present authors met DoD computer systems experts, cost accounting experts, and supply distribution experts with more than enough experience and knowledge necessary to construct a decision support tool as proposed by the model building framework in this thesis. This statement can be made simply because the present authors had comparatively no experience or expertise at the outset of this research, yet were able to construct the proposed model building framework by drawing on DoD employees' expertise. The DoD currently

employs many operations researchers, management scientists, etc., that know how to construct and operation computer simulation models for this type of research.

Computer hardware systems necessary for DC time and cost performance analysis are also already in place. Currently, they are used to track items flowing into and out of the DCs. Upon request, a DC analyst can currently provide a computer print out of any particular item. The printed report provides information on an item such as all applicable tracking numbers, the date the item is estimated to arrive at the DC, and the day the item is expected to be shipped from the DC. However, no tracking and recording of items is accomplished between and through the activities and processes within the DC itself. Also, no tracking and recording of DC activity and process time performance is currently being accomplished. Thus the DLA distribution center manager does not have the data to create a decision support tool to analyze the efficiency and effectiveness of distribution processes in terms of costs or time performance. Similarly, a manager has no means of objectively evaluating commercially successful distribution techniques, such as cross-docking, that may provide efficiency and/or effectiveness improvements in terms of cost and time.

Historical data of DoD distribution activities, processes, and item flows should be tracked and recorded and ABC analysis should be done to accurately identify resources (electricity, labor) and activities (material handling) that consume those resources. The resulting information could then be used to create a decision support tool as outlined by this thesis. This would provide managers the decision support information they need for

making contemporary and future distribution methodology decisions targeted at greater efficiency and lower cost while maintaining or enhancing effectiveness.

Research Questions Answered

The first research questions addressed were what information was necessary to build a computer simulation model and an ABC model of a DoD DC. It was found much of the data needed for such a task is not currently tracked or stored by the DoD. Some of the information needed for both the simulation and ABC models included the kinds of resources, activities, items, material flows, etc., directly involved in distribution processes. Also, for the ABC model specifically, first-stage cost drivers must be identified and used to trace resource costs to resource consuming activities. Likewise, the second-stage cost drivers must be determined to calculate the costs of activities used over a given period of time. As much information as possible should be taken from direct observation of the processes themselves. Also interviews with the workers that perform, or the managers responsible for, activities are needed to construct models that satisfactorily model the system under study. Some of the information for constructing an ABC model could be taken from DoD cost code reports.

The researchers found computer systems were used to track some types of data regarding material flow through DCs. It seems feasible programmers could alter the coding or software architecture in such systems to begin automatic tracking and *recording* of empirical distribution center activity and material flow statistics for future

inputs to simulation and ABC models, thereby creating the most valid possible decision support tool.

Another research question addressed was whether or not a computer simulation model and an ABC model could be meshed to create a decision support tool as described. This thesis proposed a framework for performing such a task. Simulations of the computer models were run, and the outputs were used as inputs to a proposed ABC model. The calculations that resulted were shown to illustrate how the tool could be direct managers' attention at critical activities that may warrant management actions, such as reduction or movement of resources to smooth resource usage. The tool could also pinpoint activities that may warrant the use of high-technology cross-docking methodology methods to make DC activities more efficient. Potential efficiency improvements could then justify the movement or elimination of distribution or storage manpower and infrastructure.

Implications of the Research

One use of the proposed decision support tool is to evaluate whether or not to implement commercially successful cross-docking methodologies. Literature reviews and site visits of commercially successful DC operations suggest DoD implementation of cross-docking would result in reduced inventories, increased distribution capacity, reduced costs, and other benefits, directly supporting the logistics goals outlined by Defense logistics planners in support of *Joint Vision 2010*.

The objective of this research was *not* to determine if cross-docking should be implemented in DoD DCs, but to identify the need for logistics improvements, show cross-docking and ABC as potential aids to make those improvements, and demonstrate a framework for building a decision support tool to determine whether of not such technologies as are utilized in cross-docking should be implemented in DoD distribution centers.

It should be emphasized this tool, combining computer simulation and a proposed ABC model, is not intended to be a decision tool, but rather a decision *support* tool. In this light, Defense planners who are ultimately responsible for making logistics infrastructure decisions would be better informed to do so.

Another potential use for the proposed decision support model would be 'what-if' analyses, or 'gaming' of potential DC setups, beyond the cross-docking decision. For example, managers using the generic model of this research may wish to further modify the Altered Model to eliminate the consolidation activities, as suggested by the flow path analyses of Chapter Four. In Chapter Three is was shown how easy it is to make such changes in a computer simulation program to model the changes in the DC. Such use of the model saves the money and customer support costs of stopping actual DC operations to experiment with a proposed distribution concept.

As shown in the ABC analysis in Chapter 4, the proposed decision support tool can also be used to pinpoint management's attention on activities that need to be managed away. For example, in the generic models of this research the percentage of available pallet processing activity used went from 62.6 percent down to 5.8 percent after

incorporating the additional cross-docking methodologies. These results would pinpoint the pallet processing activity as a potential activity to try to manage away totally or perhaps combine with some other activity to better utilize resource capacity.

Similarly, a manager could simply model a current DC operation just to see what percentage of available resource capacity is being used at each activity. Managers could then see where a high percentage of activities are being used and where some activities are using relatively little of their available resource capacity. Once such imbalances are identified, managers could decide on the spot to move resources around to balance out the workload. They may also decide to model such a change, prior doing it in the actual DC, to see the impacts such a change would have on overall operations. Again, such modeling allows managers to estimate change impacts without interrupting DC mission performance.

Another implication of this research is for capacity planning. The ABC model outputs showed the overall used capacity of the Current Model to be 48.2 percent (51.8 percent unused) under normal operating conditions. This may be unacceptable to military planners who want at least, say, 70 percent unused capacity during peacetime so the DC could handle surges during contingencies. Note the Altered model showed an overall capacity usage of 28.5 percent (71.5 percent unused). Thus managers can use the proposed modeling framework to design or alter a DC for a particular capacity goal and see the differences in cost between an existing DC and that capable of handling a wartime surge.

Limitations and Suggestions for Future Research

The authors recognize several limitations and opportunities for improvements and future research. For example, simulation experiments for an actual DC would likely need to run for a year, rather than two months. Also, double shifts per day and related shift change activities should likely be considered for a more valid simulation model. A specific suggestion for future research would be to collect empirical statistics of an actual DC operation as inputs to the simulation and ABC models to provide stronger evidence of the usefulness of the decision support tool. The authors realized late in the research process that empirical data for such a site-specific experiment does not currently exist, so a framework for modeling specific DC sites was constructed by modeling a generic DC operation. A researcher could take the tool provided in this work, collect DC activity data, and redo the same analyses for a specific DoD DC.

Another suggestion for future work would be to combine the two models within the tool into one computer simulation program. There likely will be pros and cons to such an endeavor. For example, combining the models would eliminate manually reading the computer simulation model outputs for inputs into Microsoft Excel spreadsheets of the ABC model. However, including all the ABC model equations into the simulation model package may very well decrease the programmer's flexibility to change the computer simulation models to simulate various distribution center activity combinations and methodologies. Also, performing ABC calculations within a simulation program may be more difficult than using Microsoft Excel spreadsheets.

Another limitation to this research was that the authors did not cost the time items spent sitting in queues awaiting resources to process them through activities. These costs may be insignificant compared to the cost of consuming the resources to process them through activities, but this could be explored in future research. Throughput cost drivers were used in the ABC model. This associated costs based on the time items spent in activities. The longer the time an item was handled, the higher the costs of resources consumed by the activity. This approach shows managers the costs of processing items through activities and suggests to them how reducing activity (or material handling) times could save costs. The overall affect of this is to encourage the behavior of speeding items through the DC at lower costs. Since overall time items spend in the DC is a primary concern in this 'throughput cost driver' approach, times items spend awaiting resources should likely also be costed to induce the reduction of these times, as with the processing of the items through the activities themselves.

Another suggestion for future research is to develop an ABC model to cost the service of distributing particular classes of items (such as bin, conveyable, palletized, bulk, etc.) and to cost the service of distributing items to particular customers. For example, items shipped to Air Force customers may require unique activities or processing, driving service costs higher than for other customers such as the Army or Navy. Using ABC, an analysis could be made of unique customer-related distribution costs, allowing managers to price services to specific customers. Also, such analyses could be used as a basis to assign legitimate prices of distribution services for each customer. This would allow differential pricing and may encourage customers to loosen

there unique distribution requirements, thus allowing cost and related price reductions. Inherent in this process, then, is the elimination of unique customer processing requirements that may reduce overall DC efficiency and effectiveness.

One final suggestion for future research would be to use linear regression to select the most appropriate cost driver to trace particular resource costs to each consuming activity.

This thesis demonstrated a framework for designing and implementing computer simulation and ABC models to provide DC managers with the means to: 1) Model and measure the time and cost performance of an existing DC operation; 2) Change the models to simulate implementation of cross-docking distribution methodologies in the same DC, and measure the time and cost performance of the such operations ; 3) Make empirically supported decisions about whether or not, and how, to improve actual DC processes for increased efficiency and effectiveness, such as with the implementation of cross-docking. The United States of America Department of Defense owns the resources, competitiveness, resourcefulness, and will necessary to achieve the organic logistics supply chain efficiencies and effectiveness of world class commercial firms like Federal Express. The proposed framework for constructing a time and cost performance decision support tool is a way to attack the distribution center dimension of this challenge. Military leaders simply must resolve to make it so.

Appendix A: Computer Simulation Models and Outputs

FORTRAN Code for both the Current and Altered Models

```
DIMENSION NSET (5000)
COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLN
R1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(
100)
COMMON QSET(5000)
EQUIVALENCE(NSET(1),QSET(1))
NNSET=5000
NCRDR=5
NPRNT=6
NTAPE=7
CALL SLAM
STOP
END
```

SLAM Code for the Current Model

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GEN,JON AND DAN,THESIS,8/22/1997,15,Y,N,Y/N,N,Y/1,72;
LIMITS,18,4,15000;
ARRAY(1,2)/1,2;
ARRAY(2,2)/.6,1;
INITIALIZE,,43200,Y;
NETWORK;
     RESOURCE/1,SV,1;Receiving area supervisor;
     RESOURCE/2,UL,2;Unload worker driving forklift;
     RESOURCE/3,BD(2),3;Two Breakdown area workers;
     RESOURCE/4,BRC,4;Bin receipt worker;
     RESOURCE/5,BST,5;Bin putaway worker;
     RESOURCE/6,BPI,6;Bin pick worker;
     RESOURCE/7,PRC,7;Pallet receipt worker;
     RESOURCE/8,PST,8;Pallet putaway worker;
     RESOURCE/9,PPI,9;Pallet pick worker;
     RESOURCE/10,BU,10;Tri-wall buildup worker;
     RESOURCE/11,PP,11;Pallet processing worker;
     RESOURCE/12,CST,12;Consolidate worker on forklift;
     RESOURCE/13,LD,13;Load workers driving forklift;
     RESOURCE/14,TLC(50),14;Tow line carts;
     RESOURCE/15,GWG(50),15;Gull wing totes;
     RESOURCE/16,BNV(300),16;Bin storage locations;
     RESOURCE/17,PNV(100),17;Pallet storage locations;
     RESOURCE/18,SSV,18;Shipping supervisor;
;
I16  CREATE,0,,1,198,1;
     ACTIVITY;
ABNV  AWAIT(16),BNV,,1;
     ACTIVITY,,,IBN;
IBN  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,UNFRM(60,2400),,;BN ST TM;
OBN  COLCT,INT(4),TM IN BINV,,1;
     ACTIVITY;
     FREE,BNV,1;
     ACTIVITY;
ABPI  AWAIT(6),BPI,,1;
     ACTIVITY;
IBPI  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,TRIAG(2,4,6),,;BN PIK;
OBPI  COLCT,INT(4),TM BIN PICK,,1;
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     ACTIVITY;
     FREE,BPI,1;
     ACTIVITY;
BMSN ASSIGN,ATRIB(3)=2,1;
     ACTIVITY;
AGW3 AWAIT(15),GWG,,1;
     ACTIVITY;
IGW3 ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,UNFRM(6,8),,;GW3;
OGW3 COLCT,INT(4),TM IN GW3,,1;
     ACTIVITY;
FGW3 FREE,GWG,1;
     ACTIVITY,,,ABR;
ABR  AWAIT(4),BRC,,1;
     ACTIVITY;
IBRC ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,TRIAG(.5,1,3),,;BRCV;
OBRC COLCT,INT(4),TM BIN RECPT,,1;
     ACTIVITY;
     FREE,BRC,1;
     ACTIVITY;
AGW  AWAIT(15),GWG,,1;
     ACTIVITY,,ATRIB(3).EQ.1;
     ACTIVITY,,ATRIB(3).EQ.2,IGW1;
IGW2 ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,UNFRM(6,8),,;GW2;
OGW2 COLCT,INT(4),TM IN GW2,,1;
     ACTIVITY;
     FREE,GWG,1;
     ACTIVITY;
ABST AWAIT(5),BST,,1;
     ACTIVITY;
IBST ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,TRIAG(2,3,4),,;BSTOR;
OBST COLCT,INT(4),TM BIN PUTAWAY,,1;
     ACTIVITY;
     FREE,BST,1;
     ACTIVITY,,,ABNV;
IGW1 ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,UNFRM(6,8),,;GW1;
OGW1 COLCT,INT(4),TM IN GW1,,1;
     ACTIVITY;
FGW1 FREE,GWG,1;
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    ACTIVITY;
ADES3 ASSIGN,ATRIB(3)=DPROBN(2,1),1;
    ACTIVITY;
PKQY  ASSIGN,ATRIB(2)=TRIAG(5,10,20),1;
    ACTIVITY;
ABU   AWAIT(10),BU,,1;
    ACTIVITY;
IBU   ASSIGN,ATRIB(4)=TNOW,1;
    ACTIVITY,TRIAG(.5,1,4),,;TW BU;
OBU   COLCT,INT(4),TM BLD TRIWALL,,1;
    ACTIVITY;
    FREE,BU,1;
    ACTIVITY;
PACK  BATCH,2/3,ATRIB(2),,FIRST,ALL(2),1;
    ACTIVITY;
ATC6  AWAIT(14),TLC,,1;
    ACTIVITY;
ITC6  ASSIGN,ATRIB(4)=TNOW,1;
    ACTIVITY,UNFRM(6,8),,;TC6;
OTC6  COLCT,INT(4),TM TLC6 USED,,1;
    ACTIVITY;
FTCS  FREE,TLC,1;
    ACTIVITY;
APP   AWAIT(11),PP,,1;
    ACTIVITY;
IPP   ASSIGN,ATRIB(4)=TNOW,1;
    ACTIVITY,TRIAG(4,5,6),,;PT PROC;
OPP   COLCT,INT(4),TM TO PROC PLTS,,1;
    ACTIVITY;
    FREE,PP,1;
    ACTIVITY;
ATC7  AWAIT(14),TLC,,1;
    ACTIVITY;
ITC7  ASSIGN,ATRIB(4)=TNOW,1;
    ACTIVITY,UNFRM(6,8),,;TC7;
OTC7  COLCT,INT(4),TM TC7 BUSY,,1;
    ACTIVITY;
    FREE,TLC,1;
    ACTIVITY;
ACST  AWAIT(12),CST,,1;
    ACTIVITY;
ICST  ASSIGN,ATRIB(4)=TNOW,1;
    ACTIVITY,TRIAG(2,5,8),,;CONSOL;
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OCST  COLCT,INT(4),TM TO CST PLT,,1;
      ACTIVITY;
      FREE,CST,1;
      ACTIVITY;
TKQY  ASSIGN,ATRIB(2)=TRIAG(30,50,60),1;
      ACTIVITY;
IBLD  ASSIGN,ATRIB(4)=TNOW,1;
      ACTIVITY;
LOAD  BATCH,2/3,ATRIB(2),,FIRST,ALL(2);
      ACTIVITY;
ASSV  AWAIT(18),SSV,,1;
      ACTIVITY;
IDOC  ASSIGN,ATRIB(4)=TNOW,1;
      ACTIVITY,TRIAG(8,15,20),,;GEN SHP DOC;
ODOC  COLCT,INT(4),TM TO WRT BOL,,1;
      ACTIVITY;
      FREE,SSV,1;
      ACTIVITY;
      UNBATCH,2,1;
      ACTIVITY;
OBLD  COLCT,INT(4),TM WTG TO SHIP,,1;
      ACTIVITY;
ALD   AWAIT(13),LD,,1;
      ACTIVITY;
ILDTK ASSIGN,ATRIB(4)=TNOW,1;
      ACTIVITY,TRIAG(4,5,6),,;LD TRK;
OLTK  COLCT,INT(4),TM TO LD TRKS,,1;
      ACTIVITY;
      FREE,LD,1;
      ACTIVITY;
TSYS  COLCT,INT(1),TIME IN SYS,,1;
      ACTIVITY;
      TERMINATE;
;
I5    CREATE,0,,1,5,1;
      ACTIVITY,,,ABST;
;
I6    CREATE,0,,1,1,1;
      ACTIVITY,,,ABPI;
;
I3    CREATE,0,,1,1,1;
      ACTIVITY;
IQ3   ASSIGN,ATRIB(2)=TRIAG(5,10,20),1;
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```
     ACTIVITY;
ID3  ASSIGN,ATRIB(3)=DPROBN(2,1),1;
     ACTIVITY;
ABDT AWAIT(3),BD,,1;
     ACTIVITY,,.95;
     ACTIVITY,,.05,IBDP;
IBDT ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,TRIAG(.2,.3,.4),,;BDBIN;
OBDT COLCT,INT(4),TM ITEM INTO CTC,,1;
     ACTIVITY;
     FREE,BD,1;
     ACTIVITY;
ICTC ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY;
CTC  BATCH,1,ATRIB(2),,FIRST,ALL(2),1;
     ACTIVITY;
APSH AWAIT(3),BD,,1;
     ACTIVITY;
IPSH ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,TRIAG(2.5,3,3.5),,;PUSH;
OPSH COLCT,INT(4),TM TO PSH CTC,,1;
     ACTIVITY;
     FREE,BD,1;
     ACTIVITY;
MT   UNBATCH,2,1;
     ACTIVITY;
OCTC COLCT,INT(4),TM IN CANVS CART,,1;
     ACTIVITY,,,ABR;
IBDP ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,TRIAG(.5,1,1.5),,;BDPI;
OBDP COLCT,INT(4),TM TWITEM TO TLC,,1;
     ACTIVITY;
FBD  FREE,BD,1;
     ACTIVITY;
ATC1 AWAIT(14),TLC,,1;
     ACTIVITY;
ITC1 ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,UNFRM(6,8),,;TLC1;
OTC1 COLCT,INT(4),TM TC1 BUSY;
     ACTIVITY;
     FREE,TLC,1;
     ACTIVITY;
APRC AWAIT(7),PRC,,1;
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     ACTIVITY;
IPRC  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,TRIAG(1,2,4),,;PT RCV;
OPRC  COLCT,INT(4),TM PALLET RECV,,1;
     ACTIVITY;
     FREE,PRC,1;
     ACTIVITY;
ATCS  AWAIT(14),TLC,,1;
     ACTIVITY,,ATRIB(3).EQ.2;
     ACTIVITY,,ATRIB(3).EQ.1,ITC4;
DES2  ASSIGN,ATRIB(3)=DPROBN(2,1),1;
     ACTIVITY,,ATRIB(2).NE.2;
     ACTIVITY,,ATRIB(2).EQ.2,ITC3;
ITC2  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,UNFRM(6,8),,;TC2;
OTC2  COLCT,INT(4),TM TC2 BUSY,,1;
     ACTIVITY;
     FREE,TLC,1;
     ACTIVITY,,,PKQY;
ITC3  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,UNFRM(8,10),,;TC3;
OTC3  COLCT,INT(4),TM TLC3 BUSY,,1;
     ACTIVITY,,,FTCS;
ITC4  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,UNFRM(6,8),,;TC4;
OTC4  COLCT,INT(4),TM TLC4 BUSY,,1;
     ACTIVITY;
     FREE,TLC,1;
     ACTIVITY;
APST  AWAIT(8),PST,,1;
     ACTIVITY;
IPST  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,TRIAG(6,8,10),,;PSTOR;
OPST  COLCT,INT(4),TM PUT AWAY PLT,,1;
     ACTIVITY;
     FREE,PST,1;
     ACTIVITY;
APNV  AWAIT(17),PNV,,1;
     ACTIVITY;
IPNV  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,UNFRM(60,2400),,;PT ST TM;
OPNV  COLCT,INT(4),TM IN PLT INV,,1;
     ACTIVITY;
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     FREE,PNV,1;
     ACTIVITY;
APPI AWAIT(9),PPI,,1;
     ACTIVITY;
IPPI ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,TRIAG(6,9,12),,;PT PIK;
OPPI COLCT,INT(4),TM TO PICK PLTS,,1;
     ACTIVITY;
     FREE,PPI,1;
     ACTIVITY;
PMSN ASSIGN,ATRIB(3)=2,1;
     ACTIVITY;
ATC5 AWAIT(14),TLC,,1;
     ACTIVITY;
ITC5 ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,UNFRM(14,16),,;TC5;
OTC5 COLCT,INT(4),TM TLC5 BUSY,,1;
     ACTIVITY;
     FREE,TLC,1;
     ACTIVITY,,,APRC;
;
I2   CREATE,0,,1,2,1;
     ACTIVITY;
DES1 ASSIGN,ATRIB(3)=DPROBN(2,1),1;
     ACTIVITY;
AUL  AWAIT(2),UL,,1;
     ACTIVITY;
IUL  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,TRIAG(1,2,3),,;UNLD;
OUL  COLCT,INT(4),UNLOAD TIME,,1;
     ACTIVITY;
     FREE,UL,1;
     ACTIVITY,,.2;
     ACTIVITY,,.8,PTS;
TWQY ASSIGN,ATRIB(2)=TRIAG(5,10,20),1;
     ACTIVITY;
BKDN UNBATCH,2,1;
     ACTIVITY,,,ABDT;
PTS  ASSIGN,ATRIB(2)=2,1;
     ACTIVITY;
APTLD AWAIT(3),BD,,1;
     ACTIVITY;
IPTLD ASSIGN,ATRIB(4)=TNOW,1;
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```
     ACTIVITY,TRIAG(2,3,4),,;LDTLC;
OPLD  COLCT,INT(4),TM LD PLT ON TLC,,1;
     ACTIVITY;
     FREE,BD,1;
     ACTIVITY,,,ATC1;
;
I4   CREATE,0,,1,12,1;
     ACTIVITY;
ID4  ASSIGN,ATRIB(3)=DPROBN(2,1),1;
     ACTIVITY,,,ABR;
;
I10  CREATE,0,,1,1,1;
     ACTIVITY,,,ADES;
;
TRKS CREATE,RNORM(120,30),,1,,1;
     ACTIVITY;
PCS  ASSIGN,ATRIB(2)=TRIAG(3,15,30),1;
     ACTIVITY;
ASV  AWAIT(1),SV,,1;
     ACTIVITY,TRIAG(5,5,18),,;SBOL;
     FREE,SV,1;
     ACTIVITY;
OSV  COLCT,INT(1),TM SIGN BOL,,1;
     ACTIVITY;
UNLD UNBATCH,2,1;
     ACTIVITY,,,DES1;
;
I13  CREATE,0,,1,19,1;
     ACTIVITY,,,ALD;
;
I11  CREATE,0,,1,1,1;
     ACTIVITY;
ID11 ASSIGN,ATRIB(3)=DPROBN(2,1),1;
     ACTIVITY,,,APP;
;
I7   CREATE,0,,1,1,1;
     ACTIVITY;
ID7  ASSIGN,ATRIB(3)=DPROBN(2,1),1;
     ACTIVITY,,.8;
     ACTIVITY,,.2,IAB7;
IAP7 ASSIGN,ATRIB(2)=.8,1;
     ACTIVITY,,,APRC;
IAB7 ASSIGN,ATRIB(2)=1,1;
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```
     ACTIVITY,,,APRC;
;
I17  CREATE,0,,1,86,1;
     ACTIVITY,,.8;
     ACTIVITY,,.2,AB17;
AP17 ASSIGN,ATRIB(2)=2,1;
     ACTIVITY,,,APNV;
AB17 ASSIGN,ATRIB(2)=1,1;
     ACTIVITY,,,APNV;
;
I8   CREATE,0,,1,2,1;
     ACTIVITY,,.8;
     ACTIVITY,,.2,IB8;
IP8  ASSIGN,ATRIB(2)=2,1;
     ACTIVITY,,,APST;
IB8  ASSIGN,ATRIB(2)=1,1;
     ACTIVITY,,,APST;
;
I9   CREATE,0,,1,1,1;
     ACTIVITY,,.8;
     ACTIVITY,,.2,IB9;
IP9  ASSIGN,ATRIB(2)=2,1;
     ACTIVITY,,,APPI;
IB9  ASSIGN,ATRIB(2)=1,1;
     ACTIVITY,,,APPI;
     END;
;
MONTR,CLEAR,24000;
SIM;
MONTR,CLEAR,24000;
SIM;
MONTR,CLEAR,24000;
SIM;
MONTR,CLEAR,24000;
SIM;
MONTR,CLEAR,24000;
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MONTR,CLEAR,24000;
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MONTR,CLEAR,24000;
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MONTR,CLEAR,24000;
SIM;
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MONTR,CLEAR,24000;
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MONTR,CLEAR,24000;
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MONTR,CLEAR,24000;
SIM;
MONTR,CLEAR,24000;
SIM;
MONTR,CLEAR,24000;
FIN;
```

Summarized Activity Output Statistics for the Current Model

Activity Label	Rsrc Label	Rsrc no.	Description of Activity/Event	Mean across runs (hours)	Mean obs across runs	Total time (hours)
TM TO SIGN BOL	SV	1	Rcving spvsr checks load, signs BOL	0.156	158.533	24.765
UNLOAD TIME	UL	2	Fklft triwalls/plts to Brkdn (BD) workers	0.033	2444.467	81.428
TM ITEM INTO CTC	BD	3	Brkdn triwalls, binnables in canvas cart	0.005	5217.933	26.037
TM TWITEM TO TLC	BD	3	Brkdn triwalls, convybls onto TLC1	0.017	273.667	4.575
TM LD PLT ON TLC	BD	3	Ld Inbound pallets onto TLC1	0.050	1953.667	97.814
TM TO PSH CTC	BD	3	Bkdn worker push canvas cart to BRC	0.050	409.733	20.482
BIN RECPT	BRC	4	Rcpt binnables, place on GWG 1 or 2	0.025	8323.200	207.895
TM BIN PUTAWAY	BST	5	Binnable fm GWG2 to bin storage	0.050	3102.267	155.148
TM BIN PICK	BPI	6	Bin items fm inv to GWG 3	0.067	3109.133	207.414
TM PALLET RECV	PRC	7	Recpt pallet items, mv to TLC2 or 4	0.039	3571.733	138.940
TM PUT AWAY PLT	PST	8	Pallet items fm TLC 4 into pallet sto (PNV)	0.133	1336.667	178.227
TM TO PICK PLTS	PPI	9	Pallet items fm storage (PNV) to TLC5	0.150	1343.133	201.500
TM BLD TRIWALL	BU	10	Fm GW1 & TLC2 into TWs, onto TLC6	0.031	5496.133	168.182
TM TO PROC PLTS	PP	11	Plts fm TLC3 & 6 processed for shpment	0.083	2411.733	200.897
TM TO CST PLT	CST	12	Fklft plts fm TLC 7 to outbnd consol pts	0.083	2412.000	200.598
TM TO LD TRKS	LD	13	Cnsldated loads forklifted onto outbd trks	0.083	2415.800	201.182
TM TC1 BUSY	TLC1	14	Plts/plt items fm bkdn (BD) to plt recv (PRC)	0.117	2227.867	260.091
TM TC2 BUSY	TLC2	14	Plt items fm plt recv (PRC) to triw bldp (BU)	0.117	276.533	32.299
TM TLC3 BUSY	TLC3	14	Plts fm plt recv (PRC) to plt processing (PP)	0.150	1959.933	293.859
TM TLC4 BUSY	TLC4	14	Plts fm plt recv (PRC) to plt putaway (PST)	0.117	1335.333	155.804
TM TLC5 BUSY	TLC5	14	Plts fm plt pick (PPI) to plt recv (PRC)	0.250	1420.400	355.100
TM TLC6 USED	TLC6	14	Plts fm triw bldup (BU) to plt procsing (PP)	0.117	451.067	52.745
TM TC7 BUSY	TLC7	14	Plts fm plt procsng (PP) to ld consol (CST)	0.117	2412.067	281.301
TM IN GW1	GWG1	15	Binbls fm bin recv (BRC) to triw bldup (BU)	0.117	5219.333	608.922
TM IN GW2	GWG2	15	Binbls fm bin recv (BRC) to bin sto (BST)	0.117	3104.333	362.069
TM IN GW3	GWG3	15	Binbls fm bin sto (BST) to bin recv (BRC)	0.117	3109.000	362.958
TM IN BINV	BNV	16	Binnables in bin inventory location	20.478	3109.467	63674.967
TM IM PLT INV	PNV	17	Pallets in pallet inventory location	20.516	1342.533	27542.817
TM TO WRT BOL	SSV	18	Shipping supervisor cks load, writes BOL	0.238	51.333	12.229

Summarized Await Time Output Statistics for the Current Model

Run	Mean Time Items Spend Awaiting Activities (all times in numutes)									
	ASV	AUL	ABDT	ABR	APRC	ABU	APP	ACST	ALD	ASSV
1	0.000	16.309	1.608	32.316	3.509	4.627	4.870	1.451	139.276	0.015
2	0.000	16.697	1.527	23.649	3.790	4.844	5.041	1.138	149.574	0.196
3	0.000	16.871	1.679	28.517	3.882	4.260	3.711	1.208	154.458	0.000
4	0.000	15.876	1.629	33.993	3.308	5.363	4.098	1.434	150.553	0.140
5	0.000	16.081	1.672	25.939	2.947	4.767	4.449	1.157	160.703	0.148
6	0.000	15.641	1.569	23.339	3.460	4.616	4.233	1.237	147.904	0.150
7	0.000	15.724	1.640	27.238	3.432	4.377	4.422	1.310	151.786	0.176
8	0.000	16.823	1.589	29.689	3.793	4.616	4.435	1.448	149.885	0.207
9	0.000	15.930	1.446	22.554	3.342	3.275	3.648	1.050	146.566	0.045
10	0.000	16.690	1.384	23.068	3.553	3.904	3.884	1.085	152.023	0.457
11	0.000	16.096	1.540	24.013	3.444	3.925	4.102	1.184	155.690	0.198
12	0.000	16.412	1.605	28.947	3.813	4.641	4.171	1.216	146.874	0.000
13	0.000	16.529	1.493	27.902	3.665	3.983	4.653	1.120	165.804	0.000
14	0.000	17.224	1.464	24.259	4.025	5.593	6.972	1.489	154.609	0.038
15	0.000	16.998	1.572	26.287	3.741	3.767	5.113	1.077	176.077	0.284
average:	0.000	16.393	1.561	26.781	3.580	4.437	4.520	1.240	153.452	0.137

SLAM Code for the Altered Model

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GEN,JON AND DAN,THESIS,8/22/1997,15,Y,N,Y/N,N,Y/1,72;
LIMITS,18,4,15000;
ARRAY(1,2)/1,2;
ARRAY(2,2)/.4,1;
INITIALIZE,,43200,Y;
NETWORK;
     RESOURCE/1,SV,1;Receiving area supervisor;
     RESOURCE/2,UL,2;Unload worker driving forklift;
     RESOURCE/3,BD(2),3;Two Breakdown area workers;
     RESOURCE/4,BRC,4;Bin receipt worker;
     RESOURCE/5,BST,5;Bin putaway worker;
     RESOURCE/6,BPI,6;Bin pick worker;
     RESOURCE/7,PRC,7;Pallet receipt worker;
     RESOURCE/8,PST,8;Pallet putaway worker;
     RESOURCE/9,PPI,9;Pallet pick worker;
     RESOURCE/10,BU,10;Tri-wall buildup worker;
     RESOURCE/11,PP,11;Pallet processing worker;
     RESOURCE/12,CST,12;Consolidate worker on forklift;
     RESOURCE/13,LD,13;Load workers driving forklift;
     RESOURCE/14,TLC(50),14;Tow line carts;
     RESOURCE/15,GWG(50),15;Gull wing totes;
     RESOURCE/16,BNV(300),16;Bin storage locations;
     RESOURCE/17,PNV(100),17;Pallet storage locations;
     RESOURCE/18,SSV,18;Shipping supervisor;
;
I16  CREATE,0,,1,67,1;
     ACTIVITY;
ABNV  AWAIT(16),BNV,,1;
     ACTIVITY,,,IBN;
IBN  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,UNFRM(60,2400),,;BN ST TM;
OBN  COLCT,INT(4),TM IN BINV,,1;
     ACTIVITY;
     FREE,BNV,1;
     ACTIVITY;
ABPI  AWAIT(6),BPI,,1;
     ACTIVITY;
IBPI  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,TRIAG(2,4,6),,;BN PIK;
OBPI  COLCT,INT(4),TM BIN PICK,,1;
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     ACTIVITY;
     FREE,BPI,1;
     ACTIVITY;
BMSN  ASSIGN,ATRIB(3)=2,1;
     ACTIVITY;
AGW3  AWAIT(15),GWG,,1;
     ACTIVITY;
IGW3  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,UNFRM(6,8),,;GW3;
OGW3  COLCT,INT(4),TM IN GW3,,1;
     ACTIVITY;
FGW3  FREE,GWG,1;
     ACTIVITY,,,ABR;
ABR   AWAIT(4),BRC,,1;
     ACTIVITY;
IBRC  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,,,;BRCV;
OBRC  COLCT,INT(4),TM BIN RECPT,,1;
     ACTIVITY;
     FREE,BRC,1;
     ACTIVITY;
AGW   AWAIT(15),GWG,,1;
     ACTIVITY,,ATRIB(3).EQ.1;
     ACTIVITY,,ATRIB(3).EQ.2,IGW1;
IGW2  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,UNFRM(6,8),,;GW2;
OGW2  COLCT,INT(4),TM IN GW2,,1;
     ACTIVITY;
     FREE,GWG,1;
     ACTIVITY;
ABST  AWAIT(5),BST,,1;
     ACTIVITY;
IBST  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,TRIAG(2,3,4),,;BSTOR;
OBST  COLCT,INT(4),TM BIN PUTAWAY,,1;
     ACTIVITY;
     FREE,BST,1;
     ACTIVITY,,,ABNV;
IGW1  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,UNFRM(6,8),,;GW1;
OGW1  COLCT,INT(4),TM IN GW1,,1;
     ACTIVITY;
FGW1  FREE,GWG,1;
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     ACTIVITY;
ADES3 ASSIGN,ATRIB(3)=DPROBN(2,1),1;
     ACTIVITY;
PKQY  ASSIGN,ATRIB(2)=TRIAG(5,10,20),1;
     ACTIVITY;
ABU   AWAIT(10),BU,,1;
     ACTIVITY;
IBU   ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,TRIAG(.5,1,4),,;TW BU;
OBU   COLCT,INT(4),TM BLD TRIWALL,,1;
     ACTIVITY;
     FREE,BU,1;
     ACTIVITY;
PACK  BATCH,2/3,ATRIB(2),,FIRST,ALL(2),1;
     ACTIVITY;
ATC6  AWAIT(14),TLC,,1;
     ACTIVITY;
ITC6  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,UNFRM(6,8),,;TC6;
OTC6  COLCT,INT(4),TM TLC6 USED,,1;
     ACTIVITY;
FTCS  FREE,TLC,1;
     ACTIVITY;
APP   AWAIT(11),PP,,1;
     ACTIVITY;
IPP   ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,TRIAG(4,5,6),,;PT PROC;
OPP   COLCT,INT(4),TM TO PROC PLTS,,1;
     ACTIVITY;
     FREE,PP,1;
     ACTIVITY;
ATC7  AWAIT(14),TLC,,1;
     ACTIVITY;
ITC7  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,UNFRM(6,8),,;TC7;
OTC7  COLCT,INT(4),TM TC7 BUSY,,1;
     ACTIVITY;
FCD   FREE,TLC,1;
     ACTIVITY;
ACST  AWAIT(12),CST,,1;
     ACTIVITY;
ICST  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,TRIAG(2,5,8),,;CONSOL;
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OCST  COLCT,INT(4),TM TO CST PLT,,1;
      ACTIVITY;
      FREE,CST,1;
      ACTIVITY;
TKQY  ASSIGN,ATRIB(2)=TRIAG(30,50,60),1;
      ACTIVITY;
IBLD  ASSIGN,ATRIB(4)=TNOW,1;
      ACTIVITY;
LOAD  BATCH,2/3,ATRIB(2),,FIRST,ALL(2);
      ACTIVITY;
ASSV  AWAIT(18),SSV,,1;
      ACTIVITY;
IDOC  ASSIGN,ATRIB(4)=TNOW,1;
      ACTIVITY,TRIAG(8,15,20),,;GEN SHP DOC;
ODOC  COLCT,INT(4),TM TO WRT BOL,,1;
      ACTIVITY;
      FREE,SSV,1;
      ACTIVITY;
      UNBATCH,2,1;
      ACTIVITY;
OBLD  COLCT,INT(4),TM WTG TO SHIP,,1;
      ACTIVITY;
ALD   AWAIT(13),LD,,1;
      ACTIVITY;
ILDTK ASSIGN,ATRIB(4)=TNOW,1;
      ACTIVITY,TRIAG(4,5,6),,;LD TRK;
OLTK  COLCT,INT(4),TM TO LD TRKS,,1;
      ACTIVITY;
      FREE,LD,1;
      ACTIVITY;
TSYS  COLCT,INT(1),TIME IN SYS,,1;
      ACTIVITY;
      TERMINATE;
;
I5    CREATE,0,,1,1,1;
      ACTIVITY,,,ABST;
;
I2    CREATE,0,,1,2,1;
      ACTIVITY;
DES1  ASSIGN,ATRIB(3)=DPROBN(2,1),1;
      ACTIVITY;
AUL   AWAIT(2),UL,,1;
      ACTIVITY;
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IUL   ASSIGN,ATRIB(4)=TNOW,1;
      ACTIVITY,TRIAG(1,2,3),,;UNLD;
OUL   COLCT,INT(4),UNLOAD TIME,,1;
      ACTIVITY;
      FREE,UL,1;
      ACTIVITY,,.1;
      ACTIVITY,,.9,PTS;
TWQY  ASSIGN,ATRIB(2)=TRIAG(5,10,20),1;
      ACTIVITY;
BKDN  UNBATCH,2,1;
      ACTIVITY,,,ABDT;
ABDT  AWAIT(3),BD,,1;
      ACTIVITY,,.95;
      ACTIVITY,,.05,IBDP;
IBDT  ASSIGN,ATRIB(4)=TNOW,1;
      ACTIVITY,TRIAG(.2,.3,.4),,;BDBIN;
OBDT  COLCT,INT(4),TM ITEM INTO CTC,,1;
      ACTIVITY;
      FREE,BD,1;
      ACTIVITY;
ICTC  ASSIGN,ATRIB(4)=TNOW,1;
      ACTIVITY;
CTC   BATCH,1,ATRIB(2),,FIRST,ALL(2),1;
      ACTIVITY;
APSH  AWAIT(3),BD,,1;
      ACTIVITY;
IPSH  ASSIGN,ATRIB(4)=TNOW,1;
      ACTIVITY,TRIAG(2.5,3,3.5),,;PUSH;
OPSH  COLCT,INT(4),TM TO PSH CTC,,1;
      ACTIVITY;
      FREE,BD,1;
      ACTIVITY;
MT    UNBATCH,2,1;
      ACTIVITY;
OCTC  COLCT,INT(4),TM IN CANVS CART,,1;
      ACTIVITY,,,ABR;
IBDP  ASSIGN,ATRIB(4)=TNOW,1;
      ACTIVITY,TRIAG(.5,1,1.5),,;BDPI;
OBDP  COLCT,INT(4),TM TWITEM TO TLC,,1;
      ACTIVITY;
FBD   FREE,BD,1;
      ACTIVITY;
ATC1  AWAIT(14),TLC,,1;
```

```
     ACTIVITY;
ITC1  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,UNFRM(6,8),,;TLC1;
OTC1  COLCT,INT(4),TM TC1 BUSY;
     ACTIVITY;
     FREE,TLC,1;
     ACTIVITY;
APRC  AWAIT(7),PRC,,1;
     ACTIVITY;
IPRC  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,,,;PT RCV;
OPRC  COLCT,INT(4),TM PALLET RECV,,1;
     ACTIVITY;
     FREE,PRC,1;
     ACTIVITY;
ATCS  AWAIT(14),TLC,,1;
     ACTIVITY,,ATRIB(3).EQ.2;
     ACTIVITY,,ATRIB(3).EQ.1,ITC4;
DES2  ASSIGN,ATRIB(3)=DPROBN(2,1),1;
     ACTIVITY,,ATRIB(2).NE.2;
     ACTIVITY,,ATRIB(2).EQ.2,ITC3;
ITC2  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,UNFRM(6,8),,;TC2;
OTC2  COLCT,INT(4),TM TC2 BUSY,,1;
     ACTIVITY;
     FREE,TLC,1;
     ACTIVITY,,,PKQY;
ITC3  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,UNFRM(8,10),,;TC3;
OTC3  COLCT,INT(4),TM TLC3 BUSY,,1;
     ACTIVITY,,,FCD;
ITC4  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,UNFRM(6,8),,;TC4;
OTC4  COLCT,INT(4),TM TLC4 BUSY,,1;
     ACTIVITY;
     FREE,TLC,1;
     ACTIVITY;
APST  AWAIT(8),PST,,1;
     ACTIVITY;
IPST  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,TRIAG(6,8,10),,;PSTOR;
OPST  COLCT,INT(4),TM PUT AWAY PLT,,1;
     ACTIVITY;
```

```
     FREE,PST,1;
     ACTIVITY;
APNV  AWAIT(17),PNV,,1;
     ACTIVITY;
IPNV  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,UNFRM(60,2400),,;PT ST TM;
OPNV  COLCT,INT(4),TM IN PLT INV,,1;
     ACTIVITY;
     FREE,PNV,1;
     ACTIVITY;
APPI  AWAIT(9),PPI,,1;
     ACTIVITY;
IPPI  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,TRIAG(6,9,12),,;PT PIK;
OPPI  COLCT,INT(4),TM TO PICK PLTS,,1;
     ACTIVITY;
     FREE,PPI,1;
     ACTIVITY;
PMSN  ASSIGN,ATRIB(3)=2,1;
     ACTIVITY;
ATC5  AWAIT(14),TLC,,1;
     ACTIVITY;
ITC5  ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,UNFRM(14,16),,;TC5;
OTC5  COLCT,INT(4),TM TLC5 BUSY,,1;
     ACTIVITY;
     FREE,TLC,1;
     ACTIVITY,,,APRC;
PTS   ASSIGN,ATRIB(2)=2,1;
     ACTIVITY;
APTLD AWAIT(3),BD,,1;
     ACTIVITY;
IPTLD ASSIGN,ATRIB(4)=TNOW,1;
     ACTIVITY,TRIAG(2,3,4),,;LDTLC;
OPLD  COLCT,INT(4),TM LD PLT ON TLC,,1;
     ACTIVITY;
     FREE,BD,1;
     ACTIVITY,,,ATC1;
;
I10   CREATE,0,,1,1,1;
     ACTIVITY,,,ADES;
;
TRKS  CREATE,RNORM(120,30),,1,,1;
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```
    ACTIVITY;
PCS  ASSIGN,ATRIB(2)=TRIAG(3,15,30),1;
    ACTIVITY;
ASV  AWAIT(1),SV,,1;
    ACTIVITY,TRIAG(5,5,18),,;SBOL;
    FREE,SV,1;
    ACTIVITY;
OSV  COLCT,INT(1),TM SIGN BOL,,1;
    ACTIVITY;
UNLD UNBATCH,2,1;
    ACTIVITY,,,DES1;
;
I13  CREATE,0,,1,20,1;
    ACTIVITY,,,ALD;
;
I12  CREATE,0,,1,2,1;
    ACTIVITY;
ID12 ASSIGN,ATRIB(3)=DPROBN(2,1),1;
    ACTIVITY,,,ACST;
;
I17  CREATE,0,,1,61,1;
    ACTIVITY,,.8;
    ACTIVITY,,.2,AB17;
AP17 ASSIGN,ATRIB(2)=2,1;
    ACTIVITY,,,APNV;
AB17 ASSIGN,ATRIB(2)=1,1;
    ACTIVITY,,,APNV;
;
I8   CREATE,0,,1,1,1;
    ACTIVITY,,.8;
    ACTIVITY,,.2,IB8;
IP8  ASSIGN,ATRIB(2)=2,1;
    ACTIVITY,,,APST;
IB8  ASSIGN,ATRIB(2)=1,1;
    ACTIVITY,,,APST;
    END;
MONTR,CLEAR,24000;
SIM;
MONTR,CLEAR,24000;
SIM;
MONTR,CLEAR,24000;
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MONTR,CLEAR,24000;
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SIM;
MONTR,CLEAR,24000;
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MONTR,CLEAR,24000;
SIM;
MONTR,CLEAR,24000;
SIM;
MONTR,CLEAR,24000;
SIM;
MONTR,CLEAR,24000;
FIN;
```

Summarized Activity Output Statistics for the Altered Model

Activity Label	Rsrc Label	Rsrc no.	Description of Activity/Event	Mean across runs (hours)	Mean obs across runs	Total time (hours)
TM TO SIGN BOL	SV	1	Rcving spvsr checks load, signs BOL	0.158	160.267	25.331
UNLOAD TIME	UL	2	Fklft triwalls/plts to Brkdn (BD) workers	0.033	2474.929	82.498
TM ITEM INTO CTC	BD	3	Brkdn triwalls, binnables in canvas cart	0.005	2594.667	12.976
TM TWITEM TO TLC	BD	3	Brkdn triwalls, convybls onto TLC1	0.017	137.600	2.302
TM LD PLT ON TLC	BD	3	Ld Inbound pallets onto TLC1	0.050	2225.333	111.341
TM TO PSH CTC	BD	3	Bkdn worker push canvas cart to BRC	0.050	203.000	10.155
BIN RECPT	BRC	4	Scan binnables	0.000	3633.133	0.000
TM BIN PUTAWAY	BST	5	Binnable fm GWG2 to bin storage	0.050	1030.467	51.546
TM BIN PICK	BPI	6	Bin items fm inv to GWG 3	0.067	1038.267	69.218
TM PALLET RECV	PRC	7	Scan pallet items	0.000	3312.667	0.000
TM PUT AWAY PLT	PST	8	Pallet items fm TLC 4 into pallet sto (PNV)	0.133	948.400	126.506
TM TO PICK PLTS	PPI	9	Pallet items fm storage (PNV) to TLC5	0.150	950.467	142.390
TM BLD TRIWALL	BU	10	Fm GW1 & TLC2 into TWs, onto TLC6	0.030	2741.667	83.588
TM TO PROC PLTS	PP	11	Plts fm TLC3 & 6 processed for shpment	0.083	225.133	18.724
TM TO CST PLT	CST	12	Fklft plts fm TLC 7 to outbnd consol pts	0.084	2451.400	204.855
TM TO LD TRKS	LD	13	Cnsldated loads forklifted onto outbd trks	0.083	2452.800	204.373
TM TC1 BUSY	TLC1	14	Plts/plt items fm bkdn (BD) to plt recv (PRC)	0.117	2362.200	275.485
TM TC2 BUSY	TLC2	14	Plt items fm plt recv (PRC) to triw bldp (BU)	0.117	138.133	16.116
TM TLC3 BUSY	TLC3	14	Plts fm plt recv (PRC) to plt processing (PP)	0.150	2226.200	333.905
TM TLC4 BUSY	TLC4	14	Plts fm plt recv (PRC) to plt putaway (PST)	0.117	948.000	110.632
TM TLC5 BUSY	TLC5	14	Plts fm plt pick (PPI) to plt recv (PRC)	0.250	950.467	237.617
TM TLC6 USED	TLC6	14	Plts fm triw bldup (BU) to plt procsing (PP)	0.116	225.267	26.206
TM TC7 BUSY	TLC7	14	Plts fm plt procsng (PP) to ld consol (CST)	0.117	225.200	26.331
TM IN GW1	GWG1	15	Binbls fm bin recv (BRC) to triw bldup (BU)	0.117	2600.867	303.261
TM IN GW2	GWG2	15	Binbls fm bin recv (BRC) to bin sto (BST)	0.117	1031.667	120.418
TM IN GW3	GWG3	15	Binbls fm bin sto (BST) to bin recv (BRC)	0.117	1038.200	121.066
TM IN BINV	BNV	16	Binnables in bin inventory location	20.533	1038.267	21319.076
TM IN PLT INV	PNV	17	Pallets in pallet inventory location	20.289	951.400	19302.849
TM TO WRT BOL	SSV	18	Shipping supervisor cks load, writes BOL	0.239	52.000	12.411

Summarized Await Time Output Statistics for the Altered Model

Run	Mean Time Items Spend Awaiting Activities (all times in numutes)									
	ASV	AUL	ABDT	ABR	APRC	ABU	APP	ACST	ALD	ASSV
1	0.000	15.926	0.974	0.000	0.000	8.433	0.089	10.841	169.707	0.049
2	0.000	15.055	1.035	0.000	0.000	10.806	0.089	9.241	147.982	0.123
3	0.000	16.168	0.914	0.000	0.000	9.324	0.150	12.532	159.077	0.000
4	0.000	16.020	0.845	0.000	0.000	8.394	0.050	12.070	149.807	0.170
5	0.000	16.484	0.908	0.000	0.000	8.888	0.114	11.468	156.177	0.206
6	0.000	16.783	0.916	0.000	0.000	8.976	0.108	15.025	163.721	0.125
7	0.000	16.669	0.967	0.000	0.000	11.209	0.153	11.800	139.375	0.000
8	0.000	15.812	1.010	0.000	0.000	13.844	0.105	11.914	155.433	0.000
9	0.000	16.500	1.057	0.000	0.000	10.811	0.147	13.008	158.205	0.000
10	0.000	16.735	0.965	0.000	0.000	9.779	0.101	10.872	171.694	0.111
11	0.000	17.229	1.020	0.000	0.000	8.989	0.168	14.095	158.907	0.196
12	0.000	16.696	1.079	0.000	0.000	10.781	0.150	11.244	153.960	0.024
13	0.000	16.472	0.989	0.000	0.000	10.729	0.129	12.142	167.304	0.219
14	0.000	16.380	0.928	0.000	0.000	7.851	0.102	11.516	152.971	0.126
15	0.000	16.976	0.926	0.000	0.000	8.085	0.129	12.940	155.012	0.273
average:	0.000	16.394	0.969	0.000	0.000	9.793	0.119	12.047	157.289	0.108

Appendix B: Activity-Based Costing Models

ABC Model Calculations for Current Model of Distribution Center

First Stage Allocation of Resource Costs

A	B	C	D	E	F	G	H	I
Resource Consumption (Two Months)				First-Stage	Main Processes			
	Labor	Non-Labor	Total	Cost Driver	Receiving	Storage	Packing	Shipping
Facility Level								
Management	22000	1200	23200	% Time Allocated	12%	33%	12%	13%
Administrative Support	28000	1600	29600	# employees (%age)	6	5	3	3
Facility Costs(op + depr)	35000	95000	130000	% of Facility Space	6%	31%	8%	10%
Utilities		60000	60000	% usage	8%	20%	15%	10%
Process Level								
Data Systems/Comp Supt	8500	29000	37500	% allocated	8%	25%	8%	10%
Equipment Maintenance	22000	45000	67000	# workorders (%age)	5	10	5	5
Unit/Batch Level	Number	Salaries for	Total					
Workers	13	4800	62400	# Assigned	5	4	2	2
Supervisors	4	8000	32000	# Assigned	1	1	1	1
	Number	Capital Cost	Total					
Manual Incheck Stations	2	4000	8000		2			
Fork Lifts	4	3575	14300	# Assigned	1	2		1
Pallet Jacks	2	1400	2800	# Assigned	1			1

Resource Consumption (Two Months)				First-Stage	Main Processes			
	Labor	Non-Labor	Total	Cost Driver	Receiving	Storage	Packing	Shipping
Facility Level								
Management	22000	1200	23200	% Time Allocated	2784	7656	2784	3016
Administrative Support	28000	1600	29600	# employees (%age)	4800.00	4000.00	2400.00	2400.00
Facility Costs(op + depr)	35000	95000	130000	% of Facility Space	7800.00	40300.00	10400.00	13000.00
Utilities		60000	60000	% usage	4800.00	12000.00	9000.00	6000.00
Process Level								
Data Systems/Comp Supt	8500	29000	37500	% allocated	3000.00	9375.00	3000.00	3750.00
Equipment Maintenance	22000	45000	67000	# workorders (%age)	6203.70	12407.41	6203.70	6203.70
Unit/Batch Level	Number	Salaries	Total					
Workers	13	4800	62400	# Assigned	24000	19200	9600	9600
Supervisors	4	8000	32000	# Assigned	8000	8000	8000	8000
	Number	Capital Cost	Total					
Manual Incheck Stations	2	4000	8000		8000	0	0	0
Fork Lifts	4	3575	14300	# Assigned	3575	7150	0	3575
Pallet Jacks	2	1400	2800	# Assigned	1400	0	0	1400
					74362.70	120088.41	51387.70	56944.70

	First Stage Allocation of Resource Costs Continued			
J	K	L	M	
Support Activities		Resource Consumption continued		
Towline Cart	Gullwing	Other Depts	Total	
5%	5%	20%	100%	
0	0	20	37	
10%	5%	30%	100%	
15%	10%	22%	100%	
20%	14%	15%	100%	
15	12	2	54	
-	-	-	13	
-	-	-	4	
			2	
-	-	-	4	
-	-	-	2	
Support Activities			Sum	
Towline Cart	Gullwing		Verification	
1160	1160	4640	23200.00	
0.00	0.00	16000.00	29600.00	
13000.00	6500.00		91000.00	
9000.00	6000.00		46800.00	
7500.00	5250.00	5625.00	37500.00	
18611.11	14888.89	2481.48	67000.00	
			62400.00	
			32000.00	
			8000.00	
			14300.00	
			2800.00	
49271.11	33798.89	28746.48	414600.00	414600.00

Allocated Resources to Receiving Activities

	2 Month Costs	R.1.1	R.1.2	R.2.1	R.2.2	R.2.3	R.3.1	R.3.2	R.3.3	R.3.4
Facility Level										
Management	2784.00	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	Towline	12.50%
Administrative Support	4800.00	2.50%	12.50%	10%	10%	10%	5%	25%	Support	25%
Facility Costs(op + depr)	7800.00	0%	10%	22%	25%	25%	3%	5%	Activity	10%
Utilities	4800.00	9%	12%	12%	12.00%	12%	10%	16.00%		17.00%
Process Level										
Data Systems/Computer Supt	3000.00							50%		50%
Equipment Maintenance	6203.70	10%	35%	25%				15%		15%
Unit/Batch Level										
Workers each @	4800.00		1	1.31	0.35	0.06	0.28	1		1
Supervisors (1)	8000.00	7.73%	8.50%	8%	8%	8%	8%	8%		10%
Manual Incheck Stations	4000.00							1		1
Fork Lifts	3575.00		1							
Pallet Jacks	1400.00			1						

Cost of Resources Consumed by Receiving Activities

Facility Level	2 Month Costs	R.1.1	R.1.2	R.2.1	R.2.2	R.2.3	R.3.1	R.3.2	R.3.3	R.3.4
Management	2784.00	348.00	348.00	348.00	348.00	348.00	348.00	348.00		348.00
Administrative Support	4800.00	120.00	600.00	480.00	480.00	480.00	240.00	1200.00	Towline	1200.00
Facility Costs(op + depr)	7800.00	0.00	780.00	1716.00	1950.00	1950.00	234.00	390.00	Support	780.00
Utilities	4800.00	432.00	576.00	576.00	576.00	576.00	480.00	768.00	Activity	816.00
Process Level										
Data Systems/Computer Supt	3000.00	0.00	0.00	0.00	0.00	0.00	0.00	1500.00		1500.00
Equipment Maintenance	6203.70	620.37	2171.30	1550.93	0.00	0.00	0.00	930.56		930.56
Unit/Batch Level										
Workers	24000.00	0.00	4800.00	6297.41	1681.94	299.93	1320.73	4800.00		4800.00
Supervisors	8000.00	618.28	680.00	640.00	640.00	640.00	640.00	640.00		800.00
Manual Incheck Stations	8000.00	0.00	0.00	0.00	0.00	0.00	0.00	4000.00		4000.00
Fork Lifts	3575.00	0.00	3575.00	0.00	0.00	0.00	0.00	0.00		0.00
Pallet Jacks	1400.00	0.00	0.00	1400.00	0.00	0.00	0.00	0.00		0.00
	Total Activity Cost	2138.65	13530.30	13008.34	5675.94	4293.93	3262.73	14576.56		15174.56
	Facility Level	900.00	2304.00	3120.00	3354.00	3354.00	1302.00	2706.00		3144.00
Process Level:	Computer Support	0.00	0.00	0.00	0.00	0.00	0.00	1500.00		1500.00
	Equipment Maint.	620.37	2171.30	1550.93	0.00	0.00	0.00	930.56		930.56
	Unit/Batch Level	618.28	9055.00	8337.41	2321.94	939.93	1960.73	9440.00		9600.00

	Allocated costs to Receiving Activities Continued					
R.4.1	R.4.2	R.4.3	R.4.4	R.4.5	Verification	
Gullwing	Gullwing	Towline	Towline	Towline	100.00%	
Support	Support	Support	Support	Support	100.00%	
Activity	Activity	Activity	Activity	Activity	100.00%	
					100.00%	
					100.00%	
					100.00%	
					5.00	Other Supv
					0.66	34%
					2.00	
					1.00	
					1.00	

	Cost of Resources Consumed by Receiving Activities Cont'					
R.4.1	R.4.2	R.4.3	R.4.4	R.4.5	Verification	
					2784.00	
Gullwing	Gullwing	Towline	Towline	Towline	4800.00	
Support	Support	Support	Support	Support	7800.00	
Activity	Activity	Activity	Activity	Activity	4800.00	
					3000.00	
					6203.70	
					24000.00	
					8000.00	2701.72
					8000.00	
					3575.00	
					1400.00	
					74362.70	

Receiving Process: Activity Usage Statement (PAGE 1)

A	B	C	D	E	F	G	H	I
			Cost Driver	Capacity	Cost Per Hour	Actual	Actual Through-	Actual Hours Used
Activity	Activity Level	Cost ($)	Name (CD)	Hours Avail	($/Hr)	Throughput	Put Time(Hrs)	Total Time
R.1.1	Facility	900.00	Shipment/Hr	24.73	36.39	158.533	0.156	24.73
	Computer Spt	0.00	"	24.73	0.00	158.533	0.156	24.73
	Equip. Maint.	620.37	"	24.73	25.08	158.533	0.156	24.73
	Batch/Unit	618.28	"	24.73	25.00	158.533	0.156	24.73
R.1.2	Facility	2304.00	Pallets/Hr	320	7.20	2444.467	0.0333	81.40
	Computer Spt	0.00	"	320	0.00	2444.467	0.0333	81.40
	Equip. Maint.	2171.30	"	320	6.79	2444.467	0.0333	81.40
	Batch/Unit	9055.00	"	320	28.30	2444.467	0.0333	81.40
R.2.1	Facility	3120.00	Pallets/Hr	419.8274304	7.43	1953.667	0.05	97.68335
	Computer Spt	0.00	"	419.8274304	0.00	1954.667	0.05	97.73335
	Equip. Maint.	1550.93	"	419.8274304	3.69	1955.667	0.05	97.78335
	Batch/Unit	8337.41	"	419.8274304	19.86	1956.667	0.05	97.83335
R.2.2	Facility	3354.00	Items/Hr	112.1292116	29.91	5217.933	0.005	26.09
	Computer Spt	0.00	"	112.1292116	0.00	5217.933	0.005	26.09
	Equip. Maint.	0.00	"	112.1292116	0.00	5217.933	0.005	26.09
	Batch/Unit	2321.94	"	112.1292116	20.71	5217.933	0.005	26.09
R.2.3	Facility	3354.00	Items/Hr	19.99500967	167.74	273.667	0.017	4.65
	Computer Spt	0.00	"	19.99500967	0.00	273.667	0.017	4.65
	Equip. Maint.	0.00	"	19.99500967	0.00	273.667	0.017	4.65
	Batch/Unit	939.93	"	19.99500967	47.01	273.667	0.017	4.65
R.3.1	Facility	1302.00	Bags/Hr	88.04834834	14.79	409.733	0.05	20.49
	Computer Spt	0.00	"	88.04834834	0.00	409.733	0.05	20.49
	Equip. Maint.	0.00	"	88.04834834	0.00	409.733	0.05	20.49
	Batch/Unit	1960.73	"	88.04834834	22.27	409.733	0.05	20.49

Receiving Process: Activity Usage Statement (PAGE 2)									
J	K	L	M	N	O	P	Q	R	S
	Activity	**Activity**	**Activity**	**% Activity**	**% Activity**				
Activity	**Avail ($)**	**Used**	**Unused**	**Used**	**Unused**				
R.1.1	900.00	900.00	0.00	100.0%	0.0%				
	0.00	0.00	0.00	0.0%	0.0%				
	620.37	620.37	0.00	100.0%	0.0%				
	618.28	618.28	0.00	100.0%	0.0%				
R.1.2	2304.00	586.09	1717.91	25.4%	74.6%				
	0.00	0.00	0.00	0.0%	0.0%				
	2171.30	552.33	1618.97	25.4%	74.6%				
	9055.00	2303.39	6751.61	25.4%	74.6%				
R.2.1	3120.00	725.95	2394.05	23.3%	76.7%				
	0.00	0.00	0.00	0.0%	0.0%				
	1550.93	361.23	1189.69	23.3%	76.7%				
	8337.41	1942.89	6394.53	23.3%	76.7%		activity	% / activity	two BD workers
							r.2.1	0.65598036	1.31196072
R.2.2	3354.00	780.39	2573.61	23.3%	76.7%		r.2.2	0.175201893	0.350403786
	0.00	0.00	0.00	0.0%	0.0%		r.2.3	0.031242203	0.062484405
	0.00	0.00	0.00	0.0%	0.0%		r.3.1	0.137575544	0.275151089
	2321.94	540.26	1781.68	23.3%	76.7%		148.91	1	2
R.2.3	3354.00	780.39	2573.61	23.3%	76.7%				
	0.00	0.00	0.00	0.0%	0.0%				
	0.00	0.00	0.00	0.0%	0.0%				
	939.93	218.70	721.23	23.3%	76.7%				
R.3.1	1302.00	302.94	999.06	23.3%	76.7%				
	0.00	0.00	0.00	0.0%	0.0%				
	0.00	0.00	0.00	0.0%	0.0%				
	1960.73	456.21	1504.51	23.3%	76.7%				

Receiving Process: Activity Usage Statement (PAGE 3)

T	U	V	W	X	Y	Z	AA	AB
			Cost Driver	Capacity	Cost Per Hour	Actual	Actual Through-	Actual Hours Used
Activity	Activity Level	Cost	Name (CD)	Hours Avail	($/Hr)	Throughput	Put Time(Hrs)	Total Time
R.3.2	Facility	2706.00	Items/Hr	320	8.46	8323.2	0.025	208.08
	Computer Spt	1500.00	"	320	4.69	8323.2	0.025	208.08
	Equip. Maint.	930.56	"	320	2.91	8323.2	0.025	208.08
	Batch/Unit	9440.00	"	320	29.50	8323.2	0.025	208.08
R.3.3	Towline Cart	-	Towline	-	-	2227.867	0.117	260.66
	Support Activity	-	Cart Hour	-	-	-	-	-
R.3.4	Facility	3144.00	Pallets/Hr	320	9.83	3571.733	0.039	139.30
	Computer Spt	1500.00	"	320	4.69	3571.733	0.039	139.30
	Equip. Maint.	930.56	"	320	2.91	3571.733	0.039	139.30
	Batch/Unit	9600.00	"	320	30.00	3571.733	0.039	139.30
R.4.1	Gullwing Support	-	Gullwing hr	-	-	3104.333	0.116666667	362.17
	Activity	-	"	-	-	-	-	-
R.4.2	Gullwing Support	-	Gullwing hr	-	-	5219.333	0.116666667	608.92
	Activity	-	"	-	-	-	-	-
R.4.3	Towline Cart	-	Towline Cart	-	-	1335.333	0.116833333	156.01
	Support Activity	-	Hour	-	-	-	-	-
R.4.4	Towline Cart	-	Towline Cart	-	-	276.533	0.116833333	32.31
	Support Activity	-	Hour	-	-	-	-	-
R.4.5	Towline Cart	-	Towline Cart	-	-	1959.933	0.15	293.99
	Support Activity	-	Hour	-	-	-	-	-
		74362.70						

Receiving Process: Activity Usage Statement (PAGE 4)									
AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL
	Activity	Activity	Activity	% Activity	% Activity				
Activity	Avail ($)	Used	Unused	Used	Unused				
R.3.2	2706.00	1759.58	946.42	65.0%	35.0%				
	1500.00	975.38	524.63	65.0%	35.0%				
	930.56	605.09	325.46	65.0%	35.0%				
	9440.00	6138.36	3301.64	65.0%	35.0%				
R.3.3	-	-	-	See Support Activty					
	-	-	-	Income Statement					
R.3.4	3144.00	1368.60	1775.40	43.5%	56.5%				
	1500.00	652.96	847.04	43.5%	56.5%				
	930.56	405.08	525.48	43.5%	56.5%				
	9600.00	4178.93	5421.07	43.5%	56.5%				
R.4.1	-	-	-	See Support Activty					
	-	-	-	Income Statement					
R.4.2	-	-	-	See Support Activty					
	-	-	-	Income Statement					
R.4.3	-	-	-	See Support Activty					
	-	-	-	Income Statement					
R.4.4	-	-	-	See Support Activty					
	-	-	-	Income Statement					
R.4.5	-	-	-	See Support Activty					
	-	-	-	Income Statement					

Allocated Resources to Storage Activities	2 Month Costs	S.1.1	S.1.2	S.1.3	S.2.1	S.2.2	S.2.3	S.3.1	S.3.2	Verification
Facility Level										
Management	7656.00	16.66%	16.66%	16.66%	16.66%	16.70%	16.66%	Gullwing	Towline	100.00%
Administrative Support	4000.00	20.00%	10.00%	20.00%	20.00%	10.00%	20.00%	Support	Support	100.00%
Facility Costs(op + depr)	40300.00	2.50%	40.00%	2.50%	2.50%	50.00%	2.50%	Activity	Activity	100.00%
Utilities	12000.00	12.50%	25.00%	12.50%	12.50%	25.00%	12.50%			100.00%
Process Level										
Data Systems/Computer Supt	9375.00	5%	40%	5%	5%	40%	5%			100.00%
Equipment Maintenance	12407.41	25%	5%	20%	20%	5%	25%			100.00%
Unit/Batch Level										
Workers each @	4800.00	1		1	1		1		Other Supr	4.00
Supervisors (1)	8000.00	8%	18%	9%	8%	18%	9%		30%	70.00%
Fork Lifts	3575.00	0		0	1		1			2.00
Pallet Jacks	1400.00									0.00

Cost of Resources Consumed by Storage Activities										
Facility Level	2 Month Costs	S.1.1	S.1.2	S.1.3	S.2.1	S.2.2	S.2.3	S.3.1	S.3.2	Verification
Management	7656.00	1275.49	1275.49	1275.49	1275.49	1278.55	1275.49			7656.00
Administrative Support	4000.00	800.00	400.00	800.00	800.00	400.00	800.00	Gullwing	Towline	4000.00
Facility Costs(op + depr)	40300.00	1007.50	16120.00	1007.50	1007.50	20150.00	1007.50	Support	Support	40300.00
Utilities	12000.00	1500.00	3000.00	1500.00	1500.00	3000.00	1500.00	Activity	Activity	12000.00
Process Level										
Data Systems/Computer Supt	9375.00	468.75	3750.00	468.75	468.75	3750.00	468.75			9375.00
Equipment Maintenance	12407.41	3101.85	620.37	2481.48	2481.48	620.37	3101.85			12407.41
Unit/Batch Level										
Workers	19200.00	4800.00	0.00	4800.00	4800.00	0.00	4800.00			19200.00
Supervisors	8000.00	640.00	1440.00	720.00	640.00	1440.00	720.00		2400.00	5600.00
Fork Lifts	7150.00	0.00	0.00	0.00	3575.00	0.00	3575.00			7150.00
Pallet Jacks	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00
		S.1.1	S.1.2	S.1.3	S.2.1	S.2.2	S.2.3	S.3.1	S.3.2	120088.41
Total Activity Costs		13593.59	26605.86	13053.22	16548.22	30638.92	17248.59	0.00	0.00	120088.41
	Facility Level	4582.99	20795.49	4582.99	4582.99	24828.55	4582.99	0.00	0.00	
Process Level:	Computer Support	468.75	3750.00	468.75	468.75	3750.00	468.75	0.00	0.00	
	Equipment Maint.	3101.85	620.37	2481.48	2481.48	620.37	3101.85	0.00	0.00	
	Unit/Batch Level	5440.00	1440.00	5520.00	9015.00	1440.00	9095.00	0.00	0.00	

Storage Process: Activity Usage Statement (PAGE 1)

A	B	C	D	E	F	G	H	I
Activity	Activity Level	Cost ($)	Cost Driver Name (CD)	Capacity Hours Avail	Cost Per Hour ($/Hr)	Actual Throughput	Actual Through-Put Time(Hrs)	Actual Hours Used Total Time
S.1.1	Facility	4582.99	Binnables/Hr	320	14.32	3102.267	0.05	155.11
	Computer Spt	468.75	"	320	1.46	3102.267	0.05	155.11
	Equip. Maint.	3101.85	"	320	9.69	3102.267	0.05	155.11
	Batch/Unit	5440.00	"	320	17.00	3102.267	0.05	155.11
	Bin Storage							
S.1.2	Locations=	300						
	Facility	20795.49	Binnables/Hr	320	0.217	3109.467	20.478	63675.67
	Computer Spt	3750.00	"	320	0.039	3109.467	20.478	63675.67
	Equip. Maint.	620.37	"	320	0.006	3109.467	20.478	63675.67
	Batch/Unit	1440.00	"	320	0.015	3109.467	20.478	63675.67
S.1.3	Facility	4582.99	Binnables/Hr	320	14.32	3109	0.067	208.303
	Computer Spt	468.75	"	320	1.46	3109	0.067	208.303
	Equip. Maint.	2481.48	"	320	7.75	3109	0.067	208.303
	Batch/Unit	5520.00	"	320	17.25	3109	0.067	208.303
S.2.1	Facility	4582.99	Pallets/Hr	320	14.32	1336.667	0.133	177.78
	Computer Spt	468.75	"	320	1.46	1336.667	0.133	177.78
	Equip. Maint.	2481.48	"	320	7.75	1336.667	0.133	177.78
	Batch/Unit	9015.00	"	320	28.17	1336.667	0.133	177.78
	Pallet Storage							
S.2.2	Locations=	100						
	Facility	24828.55	Pallets/Hr	320	0.776	1342.533	20.516	27543.41
	Computer Spt	3750.00	"	320	0.117	1342.533	20.516	27543.41
	Equip. Maint.	620.37	"	320	0.019	1342.533	20.516	27543.41
	Batch/Unit	1440.00	"	320	0.045	1342.533	20.516	27543.41

Storage Process: Activity Usage Statement (PAGE 2)

J	K	L	M	N	O	P	Q	R	S	T
	Activity	Activity	Activity	% Activity	% Activity					
Activity	Available ($)	Used	Unused	Used	Unused					
S.1.1	4582.99	2221.51	2361.48	48.5%	51.5%					
	468.75	227.22	241.53	48.5%	51.5%					
	3101.85	1503.56	1598.29	48.5%	51.5%					
	5440.00	2636.93	2803.07	48.5%	51.5%					
S.1.2	20795.49	13793.40	7002.09	66.3%	33.7%					
	3750.00	2487.33	1262.67	66.3%	33.7%					
	620.37	411.48	208.89	66.3%	33.7%					
	1440.00	955.13	484.87	66.3%	33.7%					
S.1.3	4582.99	2983.28	1599.71	65.1%	34.9%					
	468.75	305.13	163.62	65.1%	34.9%					
	2481.48	1615.31	866.17	65.1%	34.9%					
	5520.00	3593.23	1926.77	65.1%	34.9%					
S.2.1	4582.99	2546.09	2036.90	55.6%	44.4%					
	468.75	260.42	208.33	55.6%	44.4%					
	2481.48	1378.59	1102.89	55.6%	44.4%					
	9015.00	5008.30	4006.70	55.6%	44.4%					
S.2.2	24828.55	21370.72	3457.84	86.1%	13.9%					
	3750.00	3227.74	522.26	86.1%	13.9%					
	620.37	533.97	86.40	86.1%	13.9%					
	1440.00	1239.45	200.55	86.1%	13.9%					

Storage Process: Activity Usage Statement (PAGE 3)

V	W	X	Y	Z	AA	AB	AC	AD
Activity	Activity Level	Cost	Cost Driver Name (CD)	Capacity Hours Avail	Cost Per Hour ($/Hr)	Actual Throughput	Actual Through-Put Time(Hrs)	Actual Hours Used Total Time
S.2.3	Facility	4582.99	Pallets/Hr	320	14.32	1343.133	0.15	201.47
	Computer Spt	468.75	"	320	1.46	1343.133	0.15	201.47
	Equip. Maint.	3101.85	"	320	9.69	1343.133	0.15	201.47
	Batch/Unit	9095.00	"	320	28.42	1343.133	0.15	201.47
S.3.1	Gullwing	-	Gullwing Hr	-	-	3109	0.117	363.75
	Support Activity	-	"	-	-	-	-	-
S.3.2	Towline Cart	-	Towline	-	-	1420.4	0.25	355.10
	Support Activity	-	Cart Hour	-	-	-	-	-
		120088.41						

Storage Process: Activity Usage Statement (PAGE 4)

AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO
Activity	Activity Avail ($)	Activity Used	Activity Unused	% Activity Used	% Activity Unused					
S.2.3	4582.99	2885.42	1697.57	63.0%	37.0%					
	468.75	295.12	173.63	63.0%	37.0%					
	3101.85	1952.91	1148.95	63.0%	37.0%					
	9095.00	5726.15	3368.85	63.0%	37.0%					
S.3.1	-	-	-	See Support Activty						
	-	-	-	Income Statement						
S.3.2	-	-	-	See Support Activty						
	-	-	-	Income Statement						

	2 Month Costs	P.1	P.2	P.3	P.4	Verification	
Allocated Resources to Packing Activities							
	2 Month Costs	**P.1**	**P.2**	**P.3**	**P.4**	**Verification**	
Facility Level							
Management	2784.00	50%	Towline	50%	Towline	100%	
Administrative Support	2400.00	50%	Support	50%	Support	100%	
Facility Costs(op + depr)	10400.00	50%	Activity	50%	Activity	100%	
Utilities	9000.00	50%		50%		100%	
Process Level							
Data Systems/Computer Supt	3000.00	60%		40%		100%	
Equipment Maintenance	6203.70	50%		50%		100%	
Unit/Batch Level							
Workers each @	4800.00	1		1		2.00	Othr Supr
Supervisors (1)	8000.00	35%		35%		70%	30%
Fork Lifts	3575.00					0.00	
Pallet Jacks	1400.00					0.00	
Cost of Resources Consumed by Packing Activities							
Facility Level	**2 Month Costs**	**P.1**	**P.2**	**P.3**	**P.4**	**Verification**	
Management	2784.00	1392.00		1392.00		2784.00	
Administrative Support	2400.00	1200.00	Towline	1200.00	Towline	2400.00	
Facility Costs(op + depr)	10400.00	5200.00	Support	5200.00	Support	10400.00	
Utilities	9000.00	4500.00	Activity	4500.00	Activity	9000.00	
Process Level							
Data Systems/Computer Supt	3000.00	1800.00		1200.00		3000.00	
Equipment Maintenance	6203.70	3101.85		3101.85		6203.70	
Unit/Batch Level							
Workers	9600.00	4800.00		4800.00		9600.00	
Supervisors	8000.00	2800.00		2800.00		5600.00	2400.00
Fork Lifts	0.00	0.00		0.00		0.00	
Pallet Jacks	0.00	0.00		0.00		0.00	
		P.1	**P.2**	**P.3**	**P.4**	51387.70	
	Total Activity Costs	24793.85		24193.85		51387.70	
	Facility Level	12292.00		12292.00			
Process Level:	**Computer Support**	1800.00		1200.00			
	Equipment Maint.	3101.85		3101.85			
	Unit/Batch Level	7600.00		7600.00			

Packing Process: Activity Usage Statement (PAGE 1)

A	B	C	D	E	F	G	H	I
Activity	Activity Level	Cost ($)	Cost Driver Name (CD)	Capacity Hours Avail	Cost Per Hour ($/Hr)	Actual Throughput	Actual Through-Put Time(Hrs)	Actual Hours Used Total Time
P.1	Facility	12292.00	Item/Hr	320	38.41	5496	0.031	170.38
	Computer Spt	1800.00	"	320	5.63	5496	0.031	170.38
	Equip. Maint.	3101.85	"	320	9.69	5496	0.031	170.38
	Batch/Unit	7600.00	"	320	23.75	5496	0.031	170.38
P.2	Towline Cart	-	Towline	-	-	451	0.117	52.77
	Support Activity	-	Cart Hour	-	-	-	-	-
P.3	Facility	12292.00	Pallet/Hr	320	38.41	2411.733	0.083	200.17
	Computer Spt	1200.00	"	320	3.75	2411.733	0.083	200.17
	Equip. Maint.	3101.85	"	320	9.69	2411.733	0.083	200.17
	Batch/Unit	7600.00	"	320	23.75	2411.733	0.083	200.17
P.4	Towline Cart	-	Towline	-	-	2412	0.117	282.20
	Support Activity	-	Cart Hour	-	-	-	-	-
		51387.70						

Packing Process: Activity Usage Statement (PAGE 2)

J	K	L	M	N	O	P	Q	R	S	T
	Activity	Activity	Activity	% Activity	% Activity					
Activity	Avail ($)	Used	Unused	Used	Unused					
P.1	12292.00	6544.57	5747.43	53.2%	46.8%					
	1800.00	958.37	841.64	53.2%	46.8%					
	3101.85	1651.50	1450.35	53.2%	46.8%					
	7600.00	4046.43	3553.57	53.2%	46.8%					
P.2	-	-	-	See Support Activty						
	-	-	-	Income Statement						
P.3	12292.00	7689.18	4602.82	62.6%	37.4%					
	1200.00	750.65	449.35	62.6%	37.4%					
	3101.85	1940.34	1161.51	62.6%	37.4%					
	7600.00	4754.13	2845.87	62.6%	37.4%					
P.4	-	-	-	See Support Activty						
	-	-	-	Income Statement						

Allocated Resources to Shipping Activities						
	2 Month Costs	Sh.1	Sh.2	Sh.3	Verification	
Facility Level						
Management	3016.00	40%	40%	20%	100%	
Administrative Support	2400.00	40%	40%	20%	100%	
Facility Costs(op + depr)	13000.00	35%	35%	30%	100%	
Utilities	6000.00	35%	35%	30%	100%	
Process Level						
Data Systems/Computer Supt	3750.00			100%	100%	
Equipment Maintenance	6203.70	40%	40%	20%	100%	
Unit/Batch Level						
Workers each @	4800.00	1	1		2	Othr Supr
Supervisors (1)	8000.00	30%	30%	4%	64%	36%
Fork Lifts	3575.00		1		1	
Pallet Jacks	1400.00	1			1	
Cost of Resources Consumed by Shipping Activities						
Facility Level	2 Month Costs	Sh.1	Sh.3	Sh.4	Verification	
Management	3016.00	1206.40	1206.40	603.20	3016.00	
Administrative Support	2400.00	960.00	960.00	480.00	2400.00	
Facility Costs(op + depr)	13000.00	4550.00	4550.00	3900.00	13000.00	
Utilities	6000.00	2100.00	2100.00	1800.00	6000.00	
Process Level						
Data Systems/Computer Supt	3750.00	0.00	0.00	3750.00	3750.00	
Equipment Maintenance	6203.70	2481.48	2481.48	1240.74	6203.70	
Unit/Batch Level						
Workers	9600.00	4800.00	4800.00	0.00	9600.00	
Supervisors	8000.00	2400.00	2400.00	305.41	5105.41	2894.59
Fork Lifts	3575.00	0.00	3575.00	0.00	3575.00	
Pallet Jacks	1400.00	1400.00	0.00	0.00	1400.00	
		Sh.1	Sh.3	Sh.4	56944.70	
	Total Activity Costs	19897.88	22072.88	12079.35	56944.70	
	Facility Level	8816.40	8816.40	6783.20		
Process Level:	Computer Support	0.00	0.00	3750.00		
	Equipment Maint.	2481.48	2481.48	1240.74		
	Unit/Batch Level	8600.00	10775.00	305.41		

Shipping Process: Activity Usage Statement (PAGE 1)

A	B	C	D	E	F	G	H	I
Activity	Activity Level	Cost ($)	Cost Driver Name (CD)	Capacity Hours Avail	Cost Per Hour ($/Hr)	Actual Throughput	Actual Through-Put Time(Hrs)	Actual Hours Used Total Time
Sh.1	Facility	8816.40	Pallet/Hr	320	27.55	2412	0.083	200.20
	Computer Spt	0.00	"	320	0.00	2412	0.083	200.20
	Equip. Maint.	2481.48	"	320	7.75	2412	0.083	200.20
	Batch/Unit	8600.00	"	320	26.88	2412	0.083	200.20
Sh.2	Facility	8816.40	Pallet/Hr	320	27.55	2415.8	0.083	200.51
	Computer Spt	0.00	"	320	0.00	2415.8	0.083	200.51
	Equip. Maint.	2481.48	"	320	7.75	2415.8	0.083	200.51
	Batch/Unit	10775.00	"	320	33.67	2415.8	0.083	200.51
Sh.3	Facility	6783.20	Truck Load/Hr	12.22	555.25	51.33	0.238	12.22
	Computer Spt	3750.00	"	12.22	306.96	51.33	0.238	12.22
	Equip. Maint.	1240.74	"	12.22	101.56	51.33	0.238	12.22
	Batch/Unit	305.41	"	12.22	25.00	51.33	0.238	12.22
		56944.70						

Shipping Process: Activity Usage Statement (PAGE 2)

J	K	L	M	N	O	P	Q	R	S	T	U
	Activity	Activity	Activity	% Activity	% Activity						
Activity	Avail ($)	Used	Unused	Used	Unused						
Sh.1	8816.40	5515.65	3300.75	62.6%	37.4%						
	0.00	0.00	0.00	0.0%	0.0%						
	2481.48	1552.45	929.04	62.6%	37.4%						
	8600.00	5380.27	3219.73	62.6%	37.4%						
Sh.2	8816.40	5524.34	3292.06	62.7%	37.3%						
	0.00	0.00	0.00	0.0%	0.0%						
	2481.48	1554.89	926.59	62.7%	37.3%						
	10775.00	6751.59	4023.41	62.7%	37.3%						
Sh.3	6783.20	6783.20	0.00	100.0%	0.0%						
	3750.00	3750.00	0.00	100.0%	0.0%						
	1240.74	1240.74	0.00	100.0%	0.0%						
	305.41	305.41	0.00	100.0%	0.0%						

Cost Per Hour of Support Activity

	Towline Cart		Gullwing
Facility Level			
Management	1160.00		1160.00
Administrative Support	0.00		0.00
Facility Costs(op + depr)	13000.00		6500.00
Utilities	9000.00		6000.00
Process Level			
Data Systems/Comp Supt	7500.00		5250.00
Equipment Maintenance	18611.11		14888.89
Total Monthly Op Costs	49,271.11		33,798.89
Towline Cart Activity	49271.11	Gullwing Activity	33798.89
# of Towcarts	50	# of Gullwings	50
Operating Hours (2 months)	320	Operating Hours (2 months)	320
Pallet-Hour Cost/ TowCart	**3.08**	Item-Hr Cost/ Gullwing	**2.11**

			Cost	Capacity	Number of	Hour-Cost Per	R.3.3		R.4.3	
Support Activity	Activity Level	Cost	Driver	Hours Avail	Towline Carts	Towline Cart	Time(hr)	Cost	Time	Cost
Towline Cart System	Management	1160.00	Pallet-hr Use	320	50	0.07	260.66	18.90	156.01	11.31
	Administrative Support	0.00	"	320	50	0.00	260.66	0.00	156.01	0.00
	Facility Costs(op + depr)	13000.00	"	320	50	0.81	260.66	211.79	156.01	126.76
	Utilities	9000.00		320	50	0.56	260.66	146.62	156.01	87.76
	Data Systems/Comp Supt	7500.00		320	50	0.47	260.66	122.18	156.01	73.13
	Equipment Maintenance	18611.11		320	50	1.16	260.66	303.20	156.01	181.47
		49271.11				3.08				
					Number of	Hour-Cost Per				
					Gullwings	Gullwing				
Gullwing System	Management	1160.00	Bin-hr Use	320	50	0.07	Continued on next sheet---			
	Administrative Support	0.00	"	320	50	0.00	"			
	Facility Costs(op + depr)	6500.00	"	320	50	0.41	"			
	Utilities	6000.00		320	50	0.38	"			
	Data Systems/Comp Supt	5250.00		320	50	0.33	"			
	Equipment Maintenance	14888.89		320	50	0.93	"			
		33798.89				2.11				

Activity Usage														
R.4.4		R.4.5		S.3.2		P.1		P.4		Activity	Activity	Activity	% Activity	% Activity
Time	Cost	Time	Cost	Time	Cost	Time	Cost	Time	Cost	Avail ($)	Used	Unused	Used	Unused
32.31	2.34	293.99	21.31	355.10	25.745	52.77	3.826	282.20	20.46	1160.00	103.90	1056.10	9.0%	91.0%
32.31	0.00	293.99	0.00	355.10	0.00	52.77	0.00	282.20	0.00	0.00	0.00	0.00	0.0%	0.0%
32.31	26.25	293.99	238.87	355.10	288.52	52.77	42.87	282.20	229.29	13000.00	1164.35	11835.65	9.0%	91.0%
32.31	18.17	293.99	165.37	355.10	199.74	52.77	29.68	282.20	158.74	9000.00	806.09	8193.91	9.0%	91.0%
32.31	15.14	293.99	137.81	355.10	166.45	52.77	24.73	282.20	132.28	7500.00	671.74	6828.26	9.0%	91.0%
32.31	37.58	293.99	341.97	355.10	413.05	52.77	61.38	282.20	328.26	18611.11	1666.91	16944.21	9.0%	91.0%
										49271.11	4412.97	44858.14		

R.4.1		R.4.2		S.3.1		Activity	Activity	Activity	% Activity	% Activity
Time(hr)	Cost	Time	Cost	Time	Cost	Avail ($)	Used	Unused	Used	Unused
362.17	26.257	608.92	44.15	363.75	26.372	1160.00	96.78	1063.22	8.3%	91.7%
362.17	0	608.92	0	363.75	0	0.00	0.00	0.00	0.0%	0.0%
362.17	147.13	608.92	247.4	363.75	147.77	6500.00	542.28	5957.72	8.3%	91.7%
362.17	135.81	608.92	228.3	363.75	136.41	6000.00	500.57	5499.43	8.3%	91.7%
362.17	118.84	608.92	199.8	363.75	119.36	5250.00	438.00	4812.00	8.3%	91.7%
362.17	337.02	608.92	566.6	363.75	338.49	14888.89	1242.15	13646.74	8.3%	91.7%
						33798.89	2819.77	30979.12		

Summary Usage Statistics For Current DC Activities							
ABC Activity Code	Description of Activity/Event	Activity Avail ($)	Activity Used	Activity Unused	% Act. Used	% Act. Unused	
R.1.1	Suprvisor check inbound shipment documents	2138.65	2138.65	0.00	100.0%	0.0%	
R.1.2	Unload shipment trailer w/forklift into BD area	13530.30	3441.80	10088.50	25.4%	74.6%	
R.2.1	BD wkr place "non-break" pallet onto TLC	13008.34	3030.06	9978.27	23.3%	76.7%	
R.2.2	BD wkr remove bin from BD pallet and put in bag	5675.94	1320.65	4355.29	23.3%	76.7%	
R.2.3	BD wkr remove pallet item frm plt and put in TLC	4293.93	999.09	3294.84	23.3%	76.7%	
R.3.1	Bkdn worker push canvas cart to bin incheck	3262.73	759.15	2503.57	23.3%	76.7%	
R.3.2	Bin Inchecker input binnables into computer syst.	14576.56	9478.41	5098.15	65.0%	35.0%	
R.3.3	Mv "pallet" items and "non-brk" plts to inck via TLC	- See Towline Cart Support Activity Below					
R.3.4	Pallet inchecker input pallets into computer system	15174.56	6605.56	8569.00	43.5%	56.5%	
R.4.1	Move binnables to storage via gullwing (GW)	- See Gullwing Support Activity Below					
R.4.2	Move binnables to packing via gullwing (GW)	- See Gullwing Support Activity Below					
R.4.3	Move "palleted" items to storage via TLC	- See Towline Cart Support Activity Below					
R.4.4	Move "palleted" items to packing via TLC	- See Towline Cart Support Activity Below					
R.4.5	Move "non-break" pallets to pallet processing	- See Towline Cart Support Activity Below					
S.1.1	Place binnables into bin storage	13593.59	6589.21	7004.38	48.5%	51.5%	
S.1.2	Storage of binnables	26605.86	17647.35	8958.51	66.3%	33.7%	
S.1.3	Pick binnables from bin storage	13053.22	8496.95	4556.27	65.1%	34.9%	
S.2.1	Place "palleted" items into pallet storage	16548.22	9193.40	7354.82	55.6%	44.4%	
S.2.2	Storage of "palleted" items	30638.92	26371.88	4267.04	86.1%	13.9%	
S.2.3	Pick "palleted" items from pallet storage	17248.59	10859.60	6388.99	63.0%	37.0%	
S.3.1	Move binnables to bin incheck via GW	- See Gullwing Support Activity Below					
S.3.2	Move "palleted" item to pallet incheck via TLC	- See Towline Cart Support Activity Below					
P.1	Pack triwall cartons with bin and "palleted" items	24793.85	13200.87	11592.99	53.2%	46.8%	
P.2	Mv packed triwalls on pallets to processeing w/TLC	- See Towline Cart Support Activity Below					
P.3	Pallet processing activity	24193.85	15134.30	9059.55	62.6%	37.4%	
P.4	Move processed pallets to shipping via TLC	- See Towline Cart Support Activity Below					
Sh.1	Fklft plts from Pall-Process to outbnd consol pts	19897.88	12448.36	7449.52	62.6%	37.4%	
Sh.2	Load consolidated pallets into outbound truck	22072.88	13830.83	8242.06	62.7%	37.3%	
Sh.3	Shipping supervisor cks load, writes BOL	12079.35	12079.35	0.00	100.0%	0.0%	
Gullwing	Gullwing Support Activity	33798.89	2819.77	30979.12	8.3%	91.7%	Sum
Towline Cart	Towline Cart Support Activity	49271.11	4412.97	44858.14	9.0%	91.0%	Verification
	Total	375457.21	180858.23	194598.98	48.2%	51.8%	414600.00

ABC Model Calculations for Altered Model of Distribution Center (Sample)

First Stage Allocation of Resource Costs

A	B	C	D	E	F	G	H	I
Resource Consumption (Two Months)				First-Stage	Main Processes			
	Labor	Non-Labor	Total	Cost Driver	Receiving	Storage	Packing	Shipping
Facility Level								
Management	22000	1200	23200	% Time Allocated	12%	33%	12%	13%
Administrative Support	28000	1600	29600	# employees (%age)	4	5	3	3
Facility Costs(op + depr)	35000	95000	130000	% of Facility Space	6%	31%	8%	10%
Utilities		60000	60000	% usage	8%	20%	15%	10%
Process Level								
Data Systems/Comp Supt	8500	29000	37500	% allocated	8%	25%	8%	10%
Equipment Maintenance	22000	45000	67000	# workorders (%age)	5	10	5	5
Unit/Batch Level	Number	Salaries	Total					
Workers	11	4800	52800	# Assigned	3	4	2	2
Supervisors	4	8000	32000	# Assigned	1	1	1	1
	Number	Capital Cost	Total					
Auto-Scan Incheck Stations	2	8000	16000		2			
Fork Lifts	4	3575	14300	# Assigned	1	2		1
Pallet Jacks	2	1400	2800	# Assigned	1			1

Resource Consumption (Two Months)				First-Stage	Main Processes			
	Labor	Non-Labor	Total	Cost Driver	Receiving	Storage	Packing	Shipping
Facility Level								
Management	22000	1200	23200	% Time Allocated	2784	7656	2784	3016
Administrative Support	28000	1600	29600	# employees (%age)	3382.86	4228.57	2537.14	2537.14
Facility Costs(op + depr)	35000	95000	130000	% of Facility Space	7800.00	40300.00	10400.00	13000.00
Utilities		60000	60000	% usage	4800.00	12000.00	9000.00	6000.00
Process Level								
Data Systems/Comp Supt	8500	29000	37500	% allocated	3000.00	9375.00	3000.00	3750.00
Equipment Maintenance	22000	45000	67000	# workorders (%age)	6203.70	12407.41	6203.70	6203.70
Unit/Batch Level	Number	Salaries	Total					
Workers	11	4800	52800	# Assigned	14400	19200	9600	9600
Supervisors	4	8000	32000	# Assigned	8000	8000	8000	8000
	Number	Capital Cost	Total					
Auto-Scan Incheck Stations	2	8000	16000		16000			
Fork Lifts	4	3575	14300	# Assigned	3575	7150	0	3575
Pallet Jacks	2	1400	2800	# Assigned	1400	0	0	1400
					71345.56	120316.98	51524.85	57081.85

	First Stage Allocation of Resource Costs Continued										
J	K	L	M	N	O	P	Q	R	S	T	U
Support Activities		Resource Consumption continued									
Towline Cart	Gullwing	Other Depts	Total								
5%	5%	20%	100%								
0	0	20	35								
10%	5%	30%	100%								
15%	10%	22%	100%								
20%	14%	15%	100%								
15	12	2	54								
-	-	-	11								
-	-	-	4								
			2								
-	-	-	4								
-	-	-	2								
Support Activities			Sum								
Towline Cart	Gullwing		Verification								
1160	1160	4640	23200.00								
0.00	0.00	16914.29	29600.00								
13000.00	6500.00		91000.00								
9000.00	6000.00		46800.00								
7500.00	5250.00	5625.00	37500.00								
18611.11	14888.89	2481.48	67000.00								
			52800.00								
			32000.00								
			14300.00								
			2800.00								
49271.11	33798.89	29660.77	397000.00	413000.00							

Summary Statistics For Cross-Docking Activities

ABC Activity Code	Description of Activity/Event	Activity Avail ($)	Activity Used	Activity Unused	% Act. Used	% Act. Unused	
R.1.1	Suprvisor check inbound shipment documents	2109.98	2109.98	0.00	100.0%	0.0%	
R.1.2	Unload shipment trailer w/forklift into BD area	13353.15	3439.07	9914.08	25.8%	74.2%	
R.2.1	BD wkr place "non-break" pallet onto TLC	14381.44	3072.44	11309.00	21.4%	78.6%	
R.2.2	BD wkr remove bin from BD pallet and put in bag	4763.17	1017.60	3745.57	21.4%	78.6%	
R.2.3	BD wkr remove pallet item frm plt and put in TLC	4016.53	858.09	3158.44	21.4%	78.6%	
R.3.1	Bkdn worker push canvas cart to bin inchck sorter	2583.79	552.00	2031.79	21.4%	78.6%	
R.3.2	GW/Auto-Scan binnables into computer syst.	13422.27	152.39	13269.88	1.1%	98.9%	
R.3.3	Mv "pallet" items and "non-brk" plts to inck via TLC	- See Towline Cart Support Activity Below					
R.3.4	Auto-Scan pallets on TLC into computer system	14020.27	145.14	13875.13	1.0%	99.0%	
R.4.1	Move binnables to storage via gullwing (GW)	- See Gullwing Support Activity Below					
R.4.2	Move binnables to packing via gullwing (GW)	- See Gullwing Support Activity Below					
R.4.3	Move "palleted" items to storage via TLC	- See Towline Cart Support Activity Below					
R.4.4	Move "palleted" items to packing via TLC	- See Towline Cart Support Activity Below					
R.4.5	Move "non-break" pallets to shipping consolidation	- See Towline Cart Support Activity Below					
S.1.1	Place binnables into bin storage	13639.31	2196.07	11443.23	16.1%	83.9%	
S.1.2	Storage of binnables	26628.72	5913.44	20715.27	22.2%	77.8%	
S.1.3	Pick binnables from bin storage	13098.94	2847.54	10251.40	21.7%	78.3%	
S.2.1	Place "palleted" items into pallet storage	16593.94	6540.98	10052.96	39.4%	60.6%	
S.2.2	Storage of "palleted" items	30661.78	18495.72	12166.06	60.3%	39.7%	
S.2.3	Pick "palleted" items from pallet storage	17294.31	7705.16	9589.15	44.6%	55.4%	
S.3.1	Move binnables to bin incheck via GW	- See Gullwing Support Activity Below					
S.3.2	Move "palleted" item to pallet incheck via TLC	- See Towline Cart Support Activity Below					
P.1	Pack triwall cartons with bin and "palleted" items	24862.42	6492.67	18369.76	26.1%	73.9%	
P.2	Mv packed triwalls on pallets to processeing w/TLC	- See Towline Cart Support Activity Below					
P.3	Pallet processing activity	24262.42	1416.78	22845.65	5.8%	94.2%	
P.4	Move processed pallets to shipping via TLC	- See Towline Cart Support Activity Below					
Sh.1	Fklft plts from Pall-Process to outbnd consol pts	19952.74	12763.01	7189.73	64.0%	36.0%	
Sh.2	Load consolidated pallets into outbound truck	22127.74	14128.44	7999.30	63.8%	36.2%	
Sh.3	Shipping supervisor cks load, writes BOL	12112.07	12112.07	0.00	100.0%	0.0%	
Gullwing	Gullwing Support Activity	33798.89	1151.83	32647.05	3.4%	96.6%	Sum
Towline Cart	Towline Cart Support Activity	49271.11	3164.21	46106.90	6.4%	93.6%	Verification
	Total	372954.97	106274.62	266680.35	28.5%	71.5%	413000.00

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REPORT DOCUMENTATION PAGE			Form Approved OMB No. 074-0188
Public reporting burden for this collection of information is estimated to average 1 hour per reponse, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of the collection of information, including suggestions for reducting this burden to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503			
1. AGENCY USE ONLY (Leave blank)	**2. REPORT DATE** September 1997	**3. REPORT TYPE AND DATES COVERED** Master's Thesis	
4. TITLE AND SUBTITLE APPLYING CROSS-DOCKING AND ACTIVITY-BASED COSTING TO MILITARY DISTRIBUTION CENTERS: A PROPOSED FRAMEWORK			**5. FUNDING NUMBERS**
6. AUTHOR(S) Dwight H. Hintz Jr., Captain, USAF Jonathan P. Elliott, First Lieutenant, USAF			
7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S) Air Force Institute of Technology 2950 P Street WPAFB OH 45433-7765			**8. PERFORMING ORGANIZATION REPORT NUMBER** AFIT/GTM/LAL/97S-3
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) WL/MTIM Attn: Michael F. Hitchcock Bldg 653, Rm 415 WPAFB OH 45433-7739			**10. SPONSORING / MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited			**12b. DISTRIBUTION CODE**
13. ABSTRACT (*Maximum 200 Words*) Current events and fiscal constraints have focused DoD planners' attention on reducing logistics costs and improving efficiency while maintaining effective combat operations support. Military leaders are seeking private industry best practices that may help the DoD achieve these goals. Two commercially successful business practices that may help the DoD achieve its goals are cross-docking and Activity-Based Costing (ABC). Cross-docking is a commercially proven approach to material distribution through a distribution center that can help reduce inventories, speed material flows, and cut related logistics activity costs. However, the DoD is faced with the challenge of costing current and potential logistics processes with an antiquated costing structure. Military planners may be able to use ABC to answer this costing challenge and help them decide whether or not to invest in cross-docking technologies. This thesis is a proposed framework for constructing a tool that may provide managers performance and cost measurements of current military distribution center operations, and estimate expected performance and cost changes as a result of incorporating high technology cross-docking methodologies. The tool incorporates computer simulation modeling to measure the time performance, and a proposed ABC model to measure available versus used capacities, and costs, of existing and potential distribution processes and activities. The use of simulation for costing of activities and product costs is an unexplored area of ABC literature. Furthermore, ABC and simulation have not been used in conjunction to simulate and cost specific activities in a DoD distribution center. The implication for this research is to provide DoD managers a decision support tool for contemporary logistics decisions.			
14. Subject Terms Logistics, Distribution Centers, Cross-docking, Activity-Based Costing, Computer Simulation Modeling, Decision Support Tool			**5. NUMBER OF PAGES** 266 **16. PRICE CODE**
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

AFIT Control Number ___AFIT/GTM/LAL/97S-3___

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